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APPLE HARVESTING AND STORAGE IN BRITISH COLUMBIA

By D. V. FISHER and S. W. PORRITT

The first apple trees in the Okanagan Valley were planted at the Okanagan Mission near Kelowna B.C. in 1862 or 1863 by Fathers P. Richard and C. J. F. Pandosy of the Oblate Order. The trees were obtained from St. Mary's Mission at Mission B.C. and are still living and bearing good crops. The old Mission house which stood at the right of the picture burned down several years ago killing a number of the original trees and damaging others.

DEPARTMENT OF AGRICULTURE
OTTAWA, CANADA

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CANADA DEPARTMENT OF AGRICULTURE

APPLE HARVESTING AND STORAGE IN BRITISH COLUMBIA

A guide to growers and storage house operators concerning the influence of orchard conditions, harvesting maturity, and storage procedure on the keeping qualities of apples.

D. V. FISHER and S. W. PORRITT

DOMINION EXPERIMENTAL STATION, SUMMERLAND, B. C.

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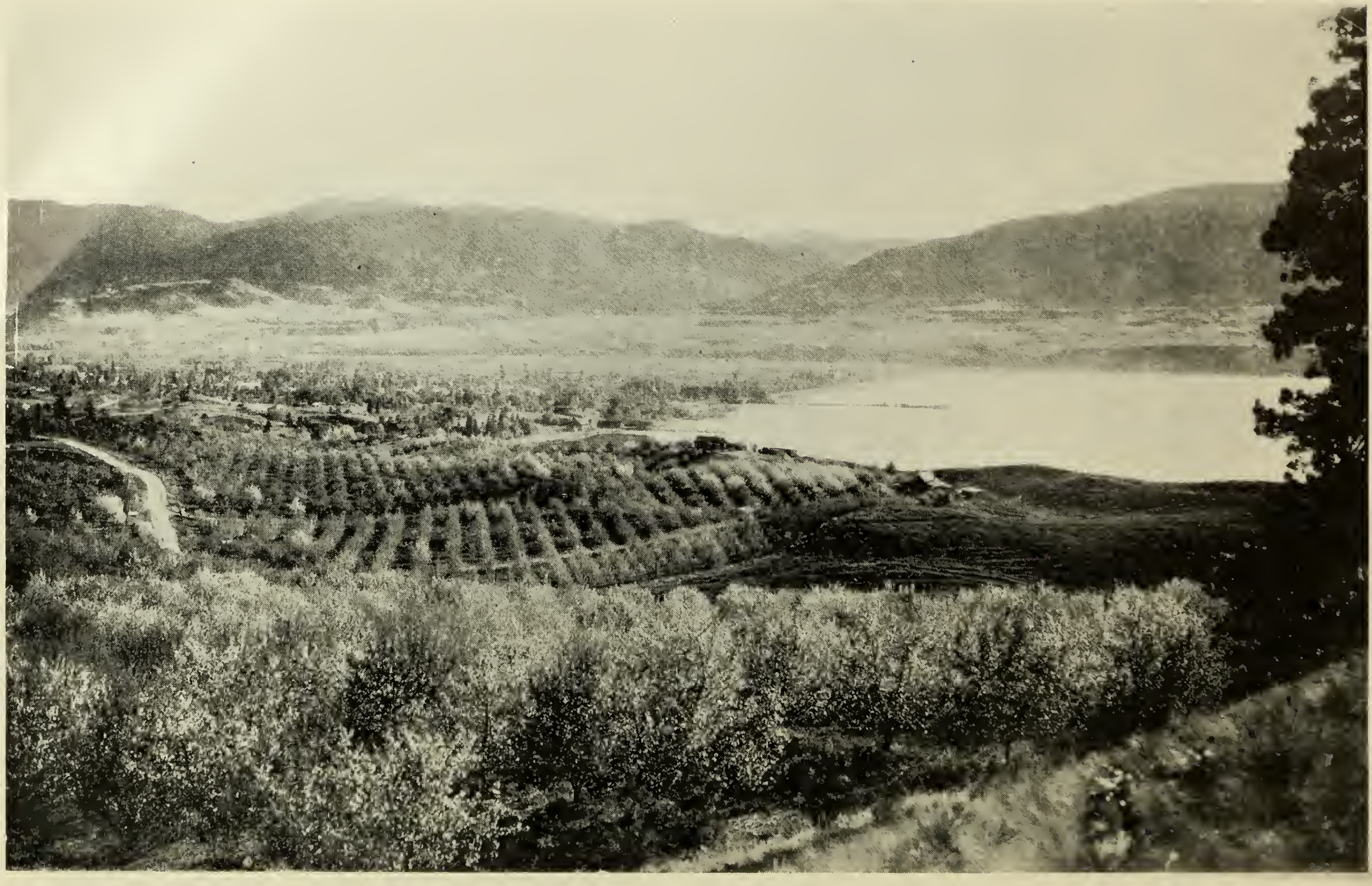

Orchards in the Okanagan Valley of British Columbia are located mainly on sloping benchlands lying at different elevations above the lake. This picture shows orchards overlooking the city of Penticton.

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TEN SIGN-POSTS TO SATISFIED CONSUMERS

1. Plan orchard operations to produce apples of medium size for the variety.
2. Harvest apples at correct stage of maturity.
3. Segregate fruit produced by young and light-crop trees and dispose of it first.
4. Handle fruit with care in orchards and in packing houses.
5. Cool fruit promptly to cold storage temperatures.
6. Provide low temperature conditions most favourable to storage life of each variety.
7. Maintain a relative humidity of 80 to 90 in storage.
8. Inspect storage stocks frequently and dispose of "weak" lots early.
9. Sell varieties in their respective ripening seasons.
10. Educate dealers and consumers to keep apples under cool, moist conditions.

INTRODUCTION

The production and marketing of British Columbia apples have developed into large scale operations. The annual crop of about eight million bushel boxes of fruit matures during a comparatively short season, and special measures must be taken to keep the fruit in good condition during the long period over which it is marketed. This involves holding much of the apple crop in cold storage warehouses pending distribution. Refrigerating plants with a total capacity of over 6,500,000 boxes have been established in the Okanagan Valley and Kootenay areas. Thus cold storage for apples is a well-recognized necessity. Nevertheless, it has in itself created a new series of problems. These problems necessitate knowledge of how to grow, harvest, and store each variety of apple so as to ensure delivery of the fruit to the consumer in first class condition.

It is to present such information in a clear, concise, and easily understood form that this bulletin has been written. The data presented have been secured mainly from experiments conducted by the Summerland Experimental Station during the past twenty-five years. In addition, the extensive literature on harvesting and storing apples in other fruit-growing areas of the world has been freely consulted.

In this bulletin an attempt has been made to present the problem of apple storage not as a procedure set apart from the rest of fruit growing practice, but as an integral part of it. Emphasis is laid upon the fact that apples grown under varying conditions from trees of unequal ages and carrying different loads must necessarily give different responses to methods of storage. The apple when it is picked is living matter and during storage the life processes are carried on in a manner at least partly predetermined by the environment under which it was grown. The storage life of an apple commences when the fruit is picked, regardless of where it is held, and continues until it reaches the consumer or becomes overripe. The conditions of storage exert a material influence on the life of the fruit.

Wherever possible, an explanation is presented for the reaction of apples to given conditions. In this way a clear conception can be formed of how an apple responds to its environment, and hence the reader is better able to apply the information he has gained to his own particular problems.

Some of the recent ideas in fruit storage are discussed critically so as to enable the reader to gain a proper perspective of these ideas in relation to established storage practices. The important problems arising from the application of new methods are emphasized.

The bulletin has been prepared in five main sections. The first two sections are primarily to acquaint the grower with those cultural and harvesting practices that tend to produce fruit of high quality and good keeping characteristics. The third and fifth sections are designed especially for the benefit of practical storage-house operators. In these sections attention is drawn to those modifications of temperature, humidity, and composition of the storage air best calculated to ensure satisfactory storage life in the more important commercial varieties of apples grown in British Columbia. In the fourth section, storage disorders of common occurrence are described, discussed, and illustrated. Summaries are included to indicate briefly the causes and methods of controlling these disorders and the harvesting and storage practices recommended. For the benefit of those interested in making a more detailed study of the storage life of apples, a list of selected references is appended.

EFFECTS OF ORCHARD CONDITIONS ON TYPE OF FRUIT PRODUCED

In order to obtain a clear understanding of the important influence which orchard conditions exert on the storage capacity of apples, it is necessary to consider some of the physiological processes which go on within the tree. These life processes are greatly affected by such factors as age of tree, amount of crop carried, water supply, nutrient supply, pruning, and thinning. Accordingly, the relationships of these factors to the physiology of the tree and the characteristics of the fruit are discussed in the following paragraphs.

Growth Status of Tree

After an apple tree is planted, its first few years are normally spent in making rapid growth, most of its food supplies being used for this purpose. Continuation of rapid growth is contingent upon a favourable supply of water, carbohydrates and minerals. The supply of nitrogen, in particular, at this stage tends to be high in relation to the number of growing points on the tree, thus stimulating rapid wood development. This vigorous growth is desirable for development of an extensive framework and profitable fruiting at an early age. Extra early fruiting may be brought about by withholding water or nitrogen, but such treatments dwarf trees and may injure the root system and therefore cannot be recommended.

Under normal circumstances the bearing condition in apple trees is attained when a balance is reached between the nitrogen uptake from the roots and carbohydrates manufactured by the leaves. When nitrogen is high, available carbohydrates tend to be utilized in wood growth; when nitrogen is reduced, carbohydrates accumulate, resulting instead in differentiation of fruit buds.

During the first few years of bearing, the young tree is still predominantly in the stage of vigorous growth, and this condition is reflected in the growth of the tree and the character of the fruit. The tree still makes vigorous terminal growth late into the summer and its tissues tend to be high in water content. Fruits from young trees are generally large, coarse in texture, often misshapen or off-type for the variety, and usually poor in quality. Such fruits are susceptible to storage disorders such as breakdown, core flush, and bitter pit.

Amount of Crop

When an apple tree reaches full bearing, which, depending on cultural conditions and variety, will be between its tenth and fifteenth year, a balance is attained between growth and fruit-bud formation. Under ideal conditions, half of the fruit spurs will blossom one year and the other half will be forming fruit buds for next year's crop. Fruit from such trees averages smaller in size than fruit from young trees, is of better quality, and less subject to storage troubles. It is suitable for long storage.

If too large a crop is carried by the tree in any one year, the fruit may be undesirably small, late in maturity, and low in quality. Furthermore, if a tree is permitted to overbear, fruit-bud formation is likely to suffer, and the tree becomes a biennial bearer producing a full crop only every second year. What has been stated about fruit from young and old trees applies also to fruit from biennial-bearing trees in their light- and heavy-crop years respectively. Apples from trees in their light-crop year are usually large, coarse, and misshapen like apples from young trees, whereas apples from the same trees in their heavy-crop year tend to be small, symmetrical, and late in maturing.

The fruit of poor storage capacity from young and light-crop trees should be segregated in the orchard. This is in contrast to general practice where the grower sends mixed loads of fruit from heavy- and light-crop trees to the packing house. Such disorders as breakdown, core flush and scald develop after the fruit has left the grower's hands. Accordingly, it is difficult for him to appreciate the fact that mixing of apples from young and light-crop trees with the fruit from full-bearing trees can be responsible for costly repacking and heavy claims. The logical place to separate the fruit from light- and heavy-crop trees is in the orchard. The small amount of care and expense involved in segregation of susceptible fruit will be repaid manyfold in reduction of losses from storage disorders. Fruit from young and light-crop trees should be sold early, preferably to processing plants.

A determined effort should be made to develop trees with an extensive bearing surface carrying a full crop of medium-sized apples every year. Such trees are profitable to the grower because they average much higher annual yields and tend to produce medium-sized apples of good colour which store satisfactorily and are therefore popular with fruit distributors and consumers. Some of the factors which contribute towards annual bearing and medium-sized fruits are adequate water supply, balanced nitrogen supply and proper pruning and thinning. Perhaps the most important and least controllable factors resulting in biennial bearing are severe winter freezes, spring frosts or poor pollinating weather which reduce the present crop and induce over-production of flower buds for the following year.

Water Supply

Since the apple tree is largely composed of water, and may use as much as 50 gallons of water per day during the heat of the summer, the importance of the water factor cannot be overestimated. The water passing continuously from the roots up the trunk and out through the leaves carries the soil nutrients and is also used in maintaining cell turgor in leaves and fruit and all other living tissue. It is used in the building of new tissue, the manufacture of sugar in the leaves and a multiplicity of other ways. Therefore, the water supply affects the tree as a whole, and so indirectly affects the fruit on the tree. Trees which receive inadequate water, even though the nutrient supply is adequate, become stunted in growth.

Where growth is somewhat stunted from lack of water, trees often produce low yields of high-quality fruit with excellent storage capacity. In cases where trees carrying a full crop run short of water late in summer and early fall, the fruit does not colour well, but often develops a dull purplish shade and remains low in quality. On the other hand, with abundance of water and high nitrogen fertilization trees tend to have a prolonged growth period, and to produce large-sized fruit poor in colour and unsuited for prolonged storage. However, in the semi-arid valleys of British Columbia where irrigation makes it possible to combine adequate moisture supplies with plenty of sunshine, heavy yields of high-quality apples can be produced, provided the grower applies water and nitrogen intelligently. In brief, it may be stated that irrigation water should be applied when the soil 8 to 12 inches below the surface has dried out to the extent that it just barely retains its shape after being squeezed in the hand. Water should be applied until the soil is thoroughly moistened. The wise irrigator digs holes to ascertain the soil moisture conditions in his orchard and applies water accordingly.

For further information on irrigation and soil moisture, the grower is referred to Canada Department of Agriculture Publications 797 on sprinkler irrigation and 779 on general orchard irrigation. These can be obtained from the Dominion Experimental Station at Summerland.

Nitrogen Supply

Differences in keeping quality of apples in relation to soil nutrient balance have been reported by a number of investigators in different fruit growing areas. With apples grown in the interior of B.C., however, impairment of keeping quality has been found to result only from over-application of nitrogen and boron. Excess or deficiency of nitrogen produces very pronounced effects upon both tree and fruit. Trees heavily fertilized with nitrogen show excessive vigour, with heavy shoot growth and large dark green leaves. Fruit from such trees is often poorly coloured, late in maturing, and of inferior quality. Furthermore, it tends to be susceptible to storage disorders such as core flush and scald.

Apples grown in sod orchards or on soils deficient in nitrogen are usually of high quality. The fruit matures early, is of good colour, fine texture, and excellent flavour. Such fruit gives very satisfactory storage performance since it retains its flavour over a long period, and rarely develops storage disorders. Apples grown under conditions of low nitrogen supply tend to be small in size and the trees are usually biennial bearing in habit. Accordingly, from the standpoint of economic production, starving apple trees for nitrogen to secure higher-quality, better-keeping fruit, should be practised with moderation. On the other hand, over-fertilization of apple orchards with nitrogen is to be avoided because of the danger of producing over-large, late-maturing, low quality fruits of poor storage capacity.

All orchards sooner or later require the addition of nitrogen. Where rainfall is adequate or irrigation water available, nitrogen may be economically supplied by the use of leguminous cover crops such as alfalfa and ladino clover. Where additional nitrogen is required it can be applied in the form of chemicals such as ammonium nitrate.

In orchards where the trees give evidence of being too abundantly supplied with nitrogen it is of advantage to plant some quick-growing annual cover crop such as oats or rye in late summer to use up any excess nitrogen. This favours development of colour in fruit and early maturity of wood growth. A great improvement in the colour and quality of the fruit may be secured by sowing the land down to sod for a few years. The grass uses up a large part of the excess nitrogen supply and checks growth in the trees. With such varieties as McIntosh, which tend to produce a large proportion of poorly-coloured fruit when over-supplied with nitrogen, it may be advisable to keep the orchard in permanent sod, applying sufficient nitrogen to maintain the growth status desired. This may require as much as 8 pounds of ammonium nitrate per mature tree per year.

Whatever method is used to control the nitrogen supply, the aim should be to keep mature trees making an average terminal growth of about 10 inches. Tree vigour should be regulated by controlling the nitrogen supply rather than by varying the degree of pruning or by varying the water supply.

For further information on soil fertility as related to apple tree requirements, the grower is referred to B.C. Department of Agriculture Horticultural Circular 76. This can be obtained from the local District Horticulturist.

Pruning and Thinning

The quality and storage capacity of apples may be indirectly influenced by pruning and thinning. Heavy pruning induces luxuriant shoot and leaf growth which delays maturity and retards colour development of the fruit. Heavy pruning and thinning both reduce the number of fruits, and hence fruit size is likely to be greatly increased. Thus through production of very large, poorly-coloured fruits subject to storage troubles, heavy pruning and thinning may materially reduce the value of the crop.

On the other hand, insufficient pruning and thinning may result in a large proportion of small-sized apples of inferior quality. Many orchards are too closely planted so that trees tend to grow into each other. Pruning in such cases often consists of "tailoring" the trees to fit one another instead of correcting the fundamental condition of over-crowding. When apple trees start touching one another a tree removal program is the only satisfactory and economical remedy. The slight loss of crop for the first few years is repaid by the immediate increase in percentage of Fancy and Extra Fancy, and reduction in Cee Grade apples.

The chief object in pruning is the development of trees which are structurally strong, carry a large bearing surface well exposed to sunlight, and have a form convenient for the performance of orchard operations such as thinning, spraying and harvesting. After the framework has been formed, pruning should consist mainly of the removal of weak wood, especially in the lower and shaded parts of the tree. Fruit produced on weak shaded wood is usually of low grade and constitutes a liability rather than an asset. Pruning in the upper parts of mature trees is sometimes necessary to bring the fruiting area down to a convenient height, and also to open up the tree so that sunlight can reach the bearing surface.

It is advisable to give trees a light pruning every year rather than to prune severely at intervals of several years. Heavy pruning tends to upset the balance of the tree, encouraging the production of water sprouts and dense foliage with consequent reduction in crop, poor colour and low quality in the fruit.

The degree of thinning which should be practised with any particular variety or tree of a variety depends on the leaf area carried by the tree and the size of fruit required. Thus with healthy McIntosh trees which commonly carry a large leaf area per foot of branch, it is seldom necessary to space the fruits more than five inches apart to secure the medium sizes which are preferred. On the other hand, with Winesap, which is characterized by small leaf area per foot of branch, and Delicious, with which comparatively large sizes are popular, thinning of fruit to nine inches apart may be required.

Blossom thinning, or early thinning is particularly to be recommended, since by removing the overload of young fruits early in the season, the tree is able to develop a set of fruit buds for next year's crop. Fruit bud initiation normally can only take place within six weeks of full bloom. Therefore on heavy crop trees where thinning is deferred until late June or early July, biennial bearing is likely to develop, with consequent undesirably large and small apples in the respective "off" and "on" years. Standard blossom thinning treatment for apples calls for a drenching spray applied to heavy crop trees at full bloom, consisting of 1·5 pints of 20 per cent sodium dinitro-cresylate or 15 ounces of 40 per cent ortho dinitro-cresol (DN2) per 100 gallons of water.

It should be clearly recognized that thinning is only one of several orchard practices which influence size of fruit. The leaves play a major role in the performance of fruit trees. In them food is manufactured for growth of the bearing surface, extension of the root system, and development of the fruit. Accordingly, growers can materially reduce severity of thinning required to produce fruit of desired size grades by adopting those cultural practices which produce a large healthy leaf surface.

EFFECTS OF HARVESTING MATURITY ON LIFE OF APPLES

Maturity Indices

The terms "maturity" and "ripeness" are often used interchangeably. Such usage, however, is erroneous as these words have quite distinct meanings. During the time that an apple is growing on the tree and is approaching the ideal picking condition, it is maturing. When it is mature it is ready to pick.

However, after it is picked, a period of time varying from a matter of a few days to a month or more, depending on variety, must elapse before the fruit is ready to eat. When it has reached prime eating condition an apple is said to be ripe. Unless an apple is picked at the proper stage of maturity it can never ripen into a high-quality product. Fortunately, the changes which take place in an apple as it approaches ideal picking condition provide fairly reliable maturity tests. These changes are outlined briefly in the following paragraphs.

As an apple approaches maturity on the tree it is subject to changes in: size, ease of picking, hardness, skin colour, flesh colour and seed colour. There are also chemical changes concerning such products in the content of the apple as starch, sugar, pectin and acid.

Size of Fruit

Size of fruit is not a satisfactory index of desirable picking condition since size is influenced by many other factors besides maturity. However, it should be pointed out that slightly immature harvesting designed to avoid loss from windfalls may be an unwise procedure, since varieties such as McIntosh and Delicious increase in size approximately one per cent per day during the picking season. Gain in size and colour may easily offset slight losses from windfalls. On the other hand, fruit should not be allowed to become overmature on the tree because of subsequent deterioration in keeping quality. There are, of course, certain minimum sizes which have to be attained before early varieties such as Transparent and Duchess become marketable. In Table 1 are given the approximate diameters of several varieties corresponding to different standard packs. The most desirable sizes are indicated by asterisks.

TABLE 1.—APPROXIMATE DIAMETERS OF APPLE VARIETIES IN STANDARD PACKS

Number of Apples per Box	Duchess	Wealthy	McIntosh	Delicious	Rome Beauty	Winesap and Stayman	Jonathan	Newtown
	in.	in.	in.	in.	in.	in.	in.	in.
64	....	....	....	....	$3\frac{9}{16}$	....	....	....
72	....	....	....	....	$3\frac{7}{16}$	....	....	....
80	....	....	....	$3\frac{5}{16}$	$3\frac{3}{8}$	....	....	....
88	....	$3\frac{9}{16}$	$3\frac{5}{16}$	$3\frac{3}{16}$	$3\frac{1}{4}$*	....	....	$3\frac{5}{16}$
96	$3\frac{3}{16}$	$3\frac{5}{16}$	$3\frac{3}{16}$	....	$3\frac{3}{16}$*	....	....	....
100	$3\frac{1}{8}$	$3\frac{3}{16}$	$3\frac{1}{8}$	$3\frac{1}{16}$*	$3\frac{1}{8}$*	$3\frac{1}{8}$*	....	$3\frac{3}{16}$*
113	$3\frac{1}{16}$*	3*	3*	$2\frac{15}{16}$*	$3\frac{1}{16}$*	$3\frac{1}{16}$*	$2\frac{15}{16}$	$3\frac{1}{16}$*
125	3*	$2\frac{15}{16}$*	$2\frac{15}{16}$*	$2\frac{7}{8}$*	3*	3*	$2\frac{7}{8}$	3*
138	$2\frac{15}{16}$*	$2\frac{7}{8}$*	$2\frac{13}{16}$*	$2\frac{13}{16}$*	$2\frac{13}{16}$	$2\frac{7}{8}$*	$2\frac{3}{4}$*	$2\frac{7}{8}$*
150	$2\frac{13}{16}$	$2\frac{13}{16}$	$2\frac{11}{16}$*	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{13}{16}$	$2\frac{11}{16}$*	$2\frac{13}{16}$
163	$2\frac{11}{16}$	$2\frac{11}{16}$	$2\frac{5}{8}$	$2\frac{5}{8}$	$2\frac{5}{8}$	$2\frac{11}{16}$	$2\frac{5}{8}$*	$2\frac{11}{16}$
180	$2\frac{9}{16}$	$2\frac{9}{16}$	$2\frac{9}{16}$	$2\frac{9}{16}$	$2\frac{9}{16}$	$2\frac{9}{16}$	$2\frac{9}{16}$*	$2\frac{9}{16}$
198	....	$2\frac{1}{2}$	$2\frac{7}{16}$	$2\frac{7}{16}$	....	$2\frac{1}{2}$	$2\frac{7}{16}$*	$2\frac{1}{2}$
216	....	$2\frac{7}{16}$	$2\frac{3}{8}$	$2\frac{3}{8}$	....	$2\frac{7}{16}$	$2\frac{3}{8}$	$2\frac{7}{16}$
234	....	....	$2\frac{1}{4}$	$2\frac{5}{16}$	....	$2\frac{5}{16}$	$2\frac{5}{16}$	$2\frac{5}{16}$

* Desirable Sizes.

Hardness

While most varieties of apples do soften appreciably as they approach picking condition, the rate of softening is variable and usually quite slow. Furthermore, other factors such as moisture supply and soil type often have a pronounced effect on the hardness of the fruit. Hardness is, therefore, of little value as a maturity test for apples.

Ease of Picking

Ease of picking is a valuable indication of maturity when harvesting apples. No variety of apple is mature until the fruit can be separated readily from the spur. By harvesting varieties such as Rome, Newtown or Wagener a few days or a week too early, a large percentage of spurs may be removed. Moreover, speed of picking is greatly reduced. On the other hand, with varieties such as McIntosh, which tend to drop freely after they reach a certain stage of maturity, it is important to harvest the crop before there is serious loss from dropping. In this connection extensive work during recent years with stop-drop hormone sprays has indicated that the dropping of McIntosh may be delayed about 9 days by the application of a dilute spray of alpha naphthalene acetic acid or naphthalene acetamide. This spray is applied when first dropping begins, at a concentration of 10 parts per million of water. A number of proprietary compounds are on the market and should be used according to manufacturers' directions. For convenience in mixing, hormone concentrates in liquid form are preferable to dry mixes. On the other hand, some stop-drop hormones are applied as a dry mix by means of aeroplane or mechanical dusters.

It should be pointed out that results from hormone sprays are variable, in some cases giving highly effective control and in other cases producing no apparent effect. Results are usually poor when cool rainy weather follows spray applications. Since serious dropping in this area seldom occurs with late varieties of apples, stop-drop sprays are not considered worthwhile for varieties maturing after McIntosh.

A word of caution is given here regarding use of stop-drop sprays. These sprays should only be used to hold apples on the tree until the time of normal maturity. They should never be used to delay harvesting beyond normal maturity, since fruit thus handled has a materially shorter storage life.

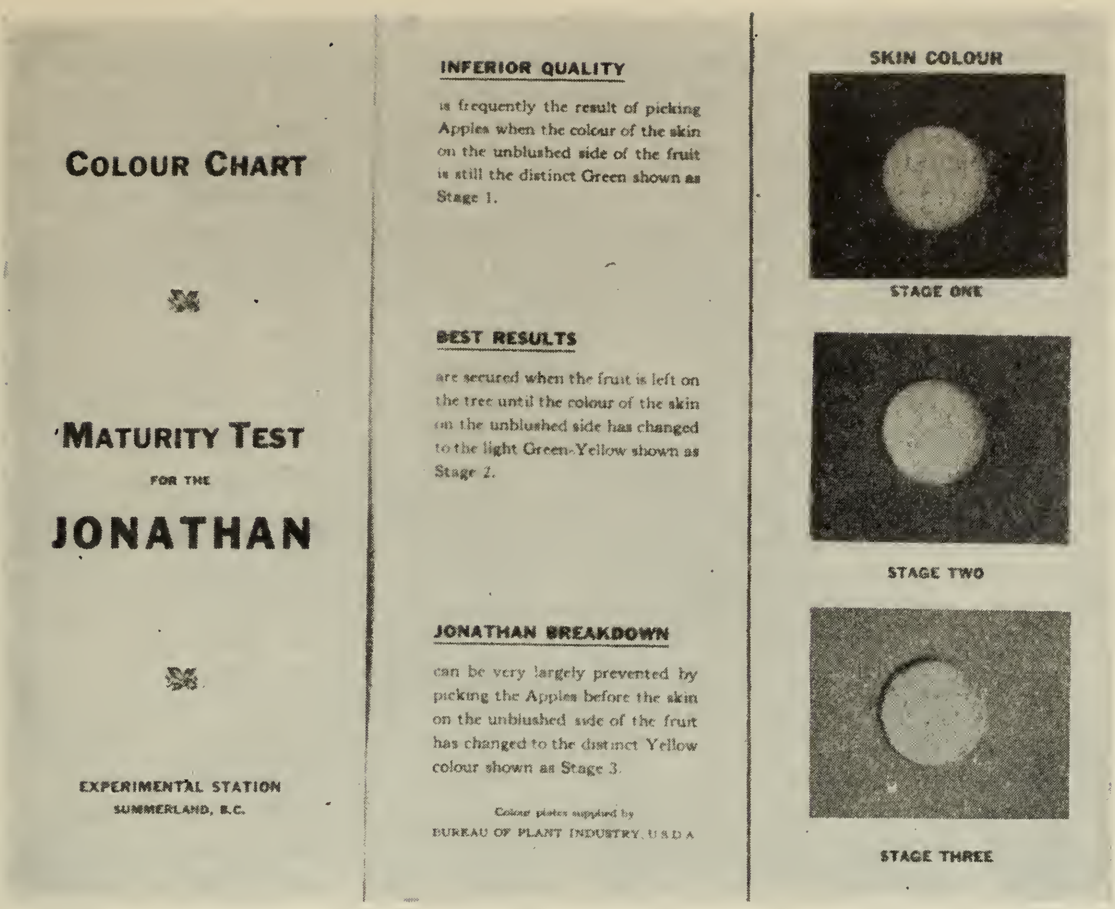
Skin Colour

The development of colour is one of the most important maturity changes which take place in red varieties. The grade of these varieties is determined mainly by the percentage of surface covered with red colour. The red colouring not only adds to the attractiveness of the fruit but also indicates in most cases high quality for the variety. In many varieties a distinct blush is evident early in the season, but most of the red colour development takes place in the last two weeks that the fruit remains on the tree. During recent years this situation has been complicated somewhat by introduction of the so-called red strains such as Starking, Richared, and Turner Red Delicious. These strains develop red colour in advance of other maturity changes such as flesh colour and sugar development. However, red strains of all varieties reach ideal picking condition about the same time as the original variety on trees of the same age grown under similar conditions.

The change in skin colour from green to greenish yellow on the unblushed surface of red apples is a useful maturity index for such varieties as McIntosh, Delicious and Jonathan. In this connection a simple colour chart has been devised by the Summerland Experimental Station which has proved very effective in reducing loss from Jonathan breakdown which is prevalent in fruit permitted to remain too long on the trees. A facsimile of this chart is presented in Figure 1. A period of about two weeks usually elapses while the fruit is passing from one stage to the next shown on the chart. This chart may be obtained by writing to the Dominion Experimental Station at Summerland, B.C.

Flesh Colour

Flesh colour changes from greenish-white to white and finally, in some varieties, to a creamy tint. This test is especially useful in determining proper harvesting maturity for red strains such as Starking, Turner Red and Richared



COLOUR CHART

'MATURITY TEST

FOR THE

JONATHAN

EXPERIMENTAL STATION
SUMMERLAND, B.C.

INFERIOR QUALITY

is frequently the result of picking Apples when the colour of the skin on the unblushed side of the fruit is still the distinct Green shown as Stage 1.

BEST RESULTS

are secured when the fruit is left on the tree until the colour of the skin on the unblushed side has changed to the light Green-Yellow shown as Stage 2.

JONATHAN BREAKDOWN

can be very largely prevented by picking the Apples before the skin on the unblushed side of the fruit has changed to the distinct Yellow colour shown as Stage 3.

Colour plates supplied by
BUREAU OF PLANT INDUSTRY, U.S.D.A.

SKIN COLOUR

STAGE ONE

STAGE TWO

STAGE THREE

FIG. 1.—A black-and-white reproduction of an actual colour chart which depicts immature, ideal, and slightly over-mature stages respectively, used for a guide in harvesting Jonathan apples. (Available from the Dominion Experimental Station at Summerland.)

Delicious, which should be picked as soon as the green colour has disappeared from the vascular bundles and the flesh appears clear white when the fruit is cut across.

Seed Colour

Seed colour is a good maturity index for McIntosh as the turning of the seeds from white to brown indicates that this variety is ready to harvest. However, seed colour is of no value as a means of determining the proper time to pick late-maturing varieties such as Delicious, Newtown and Winesap in which the seeds turn brown several weeks before the fruit is mature, or for early varieties such as Transparent and Duchess whose seeds remain partially white even though the fruit is ready to harvest.

Water Core

Development of water core is usually a sign that apples have been left too long on the tree. This is especially true of the Jonathan variety, in which water core appears first as small water-soaked areas in the region of the vascular bundles. When an apple is cut across, these water-soaked areas appear as spots arranged in a circle around the core. The Jonathan variety should be harvested promptly if even small water-soaked areas can be discerned, as in this variety water core is usually a forerunner of breakdown. On the other hand, in Delicious similar water core usually disappears during storage without injurious after-effects.

Starch-Iodine Reaction

As apples mature, the starch which they contain is gradually converted to sugar. This change takes place at the core first and, as it passes the core line, extends outward through the flesh in a mottled pattern. As a general rule, with summer and autumn varieties, much of the starch has been converted to sugar by the time the fruit reaches proper harvesting maturity; whereas with the long-keeping winter sorts, little of the starch has been changed to sugar at harvesting time. The conversion of starch to sugar takes place more rapidly in early varieties such as McIntosh than in late varieties such as Newtown.

Iodine is a specific test for starch and indicates its presence by immediately turning starch blue in colour. The starch-iodine test for maturity in apples is a simple one and can be applied with very little trouble, but must be used judiciously. The iodine solution is made with 10 grams of potassium iodide and 2·5 grams of elemental iodine dissolved in a quart of water. The potassium iodide should first be dissolved in a very small portion of the water and then the iodine may be dissolved in this concentrated solution before adding the balance of the water. In making the test, pour a small amount of the iodine solution into a shallow tray and immerse the freshly cut surface of half an apple, which has been cut in cross section. Allow the apple section to remain in the solution one minute; then remove and allow to stand one minute with cut surface up, after which the surplus iodine may be rinsed off in clean water and the starch pattern determined. The iodine solution may be used a number of times but should be kept in a dark bottle away from bright light.

It is important to follow standard methods of sampling and testing. At least 10 normal apples should be selected from five to ten normal trees which are bearing moderate to full crops. Apples from light-crop or excessively heavy-crop trees give inconsistent and unreliable results. The iodine test should be made the same day the samples are selected. Because of variation of starch content of apples, depending on time of day, apples should always be tested at the same time of day, preferably before noon. At least ten apples should be cut in cross section through the centre, and one-half of each placed in iodine. A general view of the results serves as a reliable guide to the maturity of the fruit.

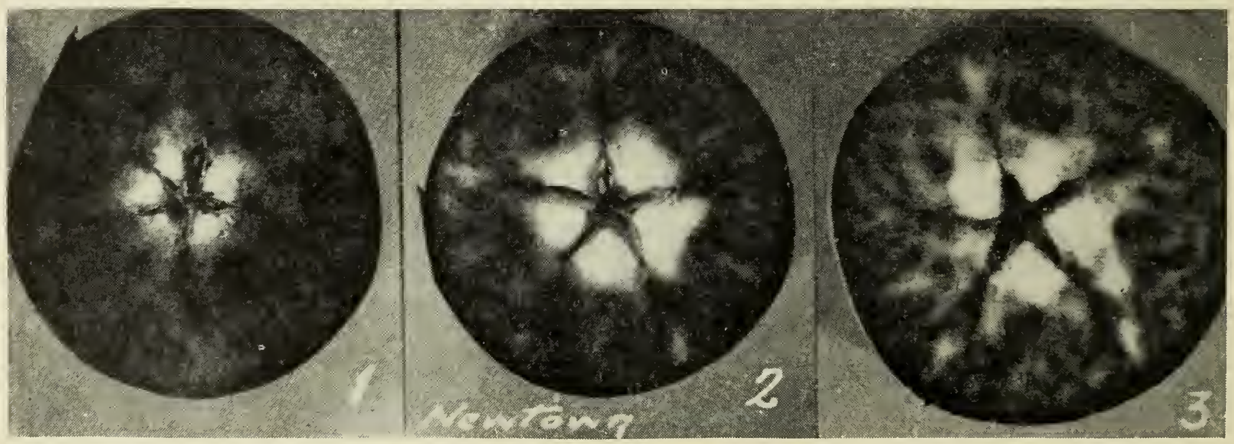


Fig. 2.—Iodine-starch maturity test for the Newtown variety. Left, immature; centre, correct maturity; right, bordering on over-maturity.

The starch-iodine reaction in Newtown is shown in Figure 2. The apple on the left was not sufficiently mature when harvested. Such fruit is susceptible to core flush in storage and fails to develop satisfactory quality. The specimen in the centre indicates a desirable stage of maturity for harvesting Newtown. It will be noted that the area within the core line is free from starch. The quality and storage life of Newtown are not impaired by leaving the fruit on the tree until it reaches the stage of maturity indicated by the starch-iodine reaction shown in the right-hand apple. However, owing to the frost hazard it is advisable to begin picking as soon as the fruit on mature trees carrying a full crop reaches stage 2. Individual fruits usually take about two weeks to pass from one stage to the next, shown in Figure 2.

Period from Blossoming to Maturity

The period elapsing between date of full bloom and attainment of correct picking maturity has received extensive investigation in recent years. It has been found with most fruits that there is a fairly high degree of constancy from year to year in the number of days intervening between full bloom and harvest. Thus it is possible, for example, to predict with fair accuracy the date of maturity for Bartlett pears or McIntosh apples, once the date of full bloom is known. Full bloom is interpreted as the stage of first fall of petals. Estimation of probable harvest date in this manner is of assistance in planning sales programs. It is recognized, of course, that variations in the maturation period occur, as for example in early-maturing nitrogen-starved orchards vs. late-maturing over-fertilized orchards. Nevertheless, data obtained in this area suggest the following information, presented in Table 2.

TABLE 2.—DAYS ELAPSING BETWEEN BLOOM AND HARVEST

Variety	*Period from Bloom to Maturity* (days)
Transparent	75
Wealthy	110
McIntosh	139
Jonathan	145
Delicious	155
Golden Delicious	160
Newtown	155 to 160
Stayman	165
Winesap	165
Rome	165

The periods given above represent the optimum; so that in practice, actual picking dates might range five days either side of the optimum. Blossom-to-harvest period is not an infallible maturity test, but a general guide for use in conjunction with other tests.

Quality

Quality is a rather vague but comprehensive term used to denote a combination of characteristics, which together make a fruit attractive to both eye and palate. Size, shape and colour are all involved; but aroma, flavour and texture are of even greater significance.

Aroma is due to the emanation from the fruit of a group of chemical products, mainly esters, which are volatile in character and are developed as the fruit ripens. (An ester results from the chemical combination of an alcohol and an acid). While these esters are produced only in very small amounts, they are of great importance because they impart to each variety its characteristic aroma and contribute to flavour.

Flavour is due in part to esters, but also to combinations of sugar, acid and tannin. Many varieties of apples, when first picked, are sour and astringent. As they ripen, the starch which they contain is converted to sugar and there is also a gradual reduction in acid and tannin content. Subtle combinations of esters, sugars, acid and tannin produce sprightly, sub-acid, and mild flavours, each of which has its individual appeal.

The texture of an apple is concerned largely with changes in the pectin content of the cell walls. When harvested, many varieties are hard and woody. As they ripen the flesh becomes softer and more palatable. However, an apple in ideal eating condition is still firm, crisp and juicy. When the pectin changes have reached the stage that the cells separate readily from one another, the apple is becoming overripe and may even become mealy. These changes are especially evident in Delicious, which has a most pleasing texture when in crisp eating condition, but may develop an unattractive mealy texture if kept too long in a warm room.

Aroma, flavour and texture are all greatly influenced by the stage of maturity at which an apple is picked. In fact, ideal quality for any variety can only be attained when the fruit is harvested at the proper stage of maturity. Cee grade McIntosh and Delicious seldom possess the characteristic flavour and aroma of these popular dessert varieties. This is due to the fact that Cee grade is largely a maturity grade, the poor colour being due to the fact that the fruit has been picked in an immature condition. At the same time it is recognized that crowded trees may produce mature apples with low colour development. On the other hand, when Delicious apples are left too long on the trees they tend to ripen very rapidly and soon become mealy in texture.

As apples near the end of their storage life, they lose their characteristic aroma and flavour, becoming flat and insipid in taste. Furthermore, their quality is sometimes marred by development of disagreeable flavours. Fruits affected with core flush often have an unpleasant taste.

The quality of apples may be seriously affected by development of storage disorders such as shrivelling, Jonathan spot, breakdown, bitter pit and core flush. Most of these disorders are caused, at least in part, by harvesting the fruit in an immature or overmature condition. Thus shrivelling, bitter pit and core flush are commonly prevalent in apples picked before they have reached optimum harvesting condition, while Jonathan spot and breakdown are usually found in apples permitted to become overmature before harvest.

With all varieties, trees with a light crop tend to produce fruit which is susceptible to storage disorders. For this reason the fruit from such trees should be carefully segregated from that produced by trees carrying a full crop. As the apples borne on trees carrying a light crop are especially susceptible to disorders such as breakdown, bitter pit, scald and core flush, they should be marketed quickly and on no account kept for long storage. Wherever possible, they should be delivered to processing plants for immediate conversion into products such as apple juice, canned apples and dehydrated apples. For such use, or for immediate sale as fresh fruit, these apples are often of satisfactory quality. For economic reasons in orchard management, it may be desirable to harvest and haul the fruit of light-crop trees from the orchard before commencing picking heavily-laden trees.

EFFECTS OF STORAGE PROCEDURE ON LIFE OF APPLES

Ripening Processes

Apples are still alive after they are picked. Accordingly, it is not surprising that they react to the various storage treatments to which they are subjected. In the broad sense, storage begins when the apple is picked and ends when it is eaten. Thus the fruit is undergoing storage when it is stacked in the orchard, when it is in the packing house, when it is under refrigeration, when it is in transit, and when it is displayed for sale in a retail store. During this period the life processes within the apple are greatly influenced by environment.

The chemical changes which take place in a ripening apple are very complex, involving conversion of starch to sugars, changes in acid and pectic substances, and the production of volatile compounds such as esters, acetaldehyde, ethyl alcohol and ethylene. The general trend and progress of these changes can be measured with a fair degree of accuracy by means of comparatively simple equipment.

Respiration is a universal phenomenon similar in its essential characteristics in both plants and animals. It is a process in which carbohydrates and acids are oxidized to carbon dioxide and water, with the resulting liberation of energy. Even when stored at 32°F., apples continue to respire. In fact, at 32°F. a bushel box of apples generates enough heat each day to raise its temperature about half a degree Fahrenheit. While the loss of sugars used in respiration during the storage life of an apple is very small, the rate of respiration does provide a very reliable index of the progress of other life processes in the fruit. The rate of respiration can be readily measured by use of the proper laboratory apparatus.

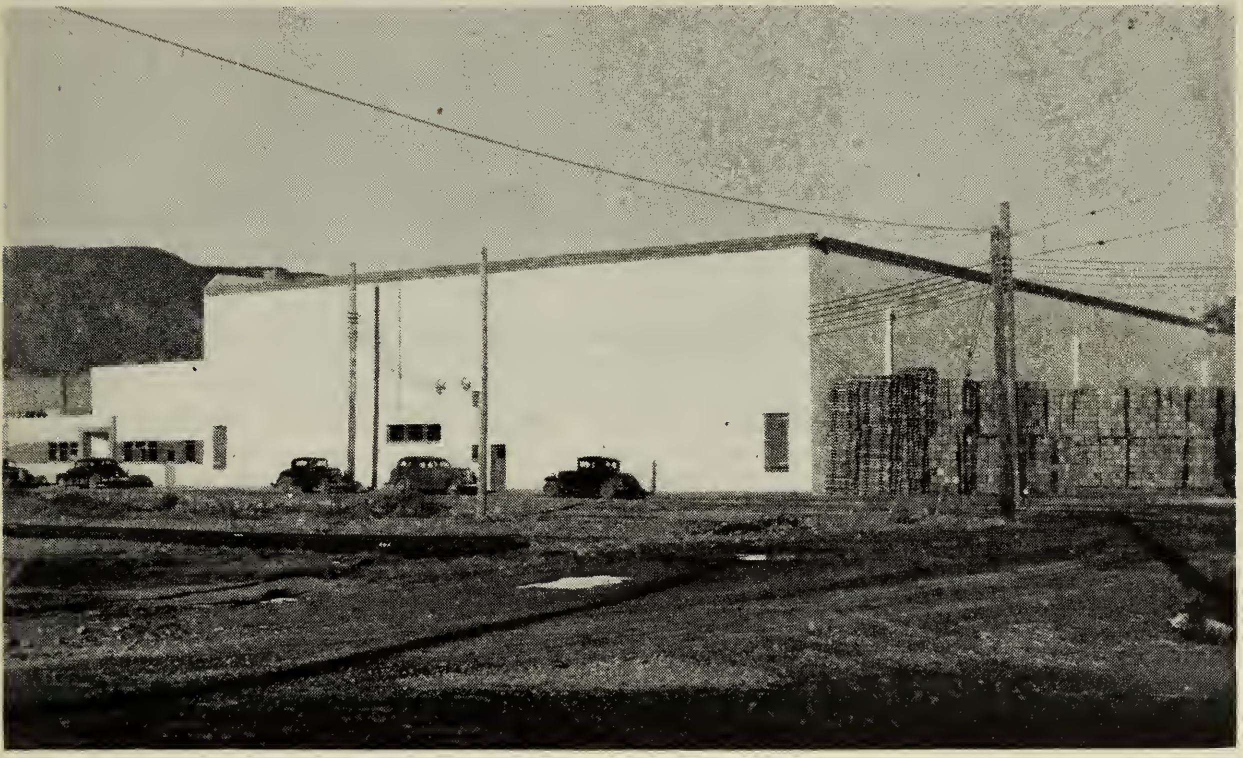


Fig. 3.—A modern fruit packing and storage house at Kelowna, B.C. Stacks of pallets and pallet loads of boxes at right. This apple cold storage with a capacity of 290,000 packed boxes is said to be the largest in the British Commonwealth.

During the ripening process, the carbohydrate content of apples consisting mainly of sugar, starch, acid and protopectin, undergoes chemical changes. At maturity most apples contain a considerable quantity of starch in addition to sugars. This starch is gradually changed over to sugar by enzyme action. The extent to which the starch has been converted to sugar can be readily determined by immersing the cut surface of an apple in a dilute iodine solution, which causes the tissues containing starch to turn blue in colour. The starch-iodine test, recommended as a maturity index for some varieties, may also be employed to register the advance of ripening of Delicious apples during storage. This test is illustrated in Figure 4 which shows progressive stages of starch content between freshly picked apples in Number 1 and mealy overripe apples in Number 8. Delicious apples pass through all these stages in their storage life regardless of temperature, the only difference being that lower temperatures retard the rate of change. At Stage 1 the fruit is tough and starchy; at Stage 4 is first eating ripe; and at Stage 8, overripe. This physiological test provides a rapid means for determining degree of ripeness of Delicious apples in storage.

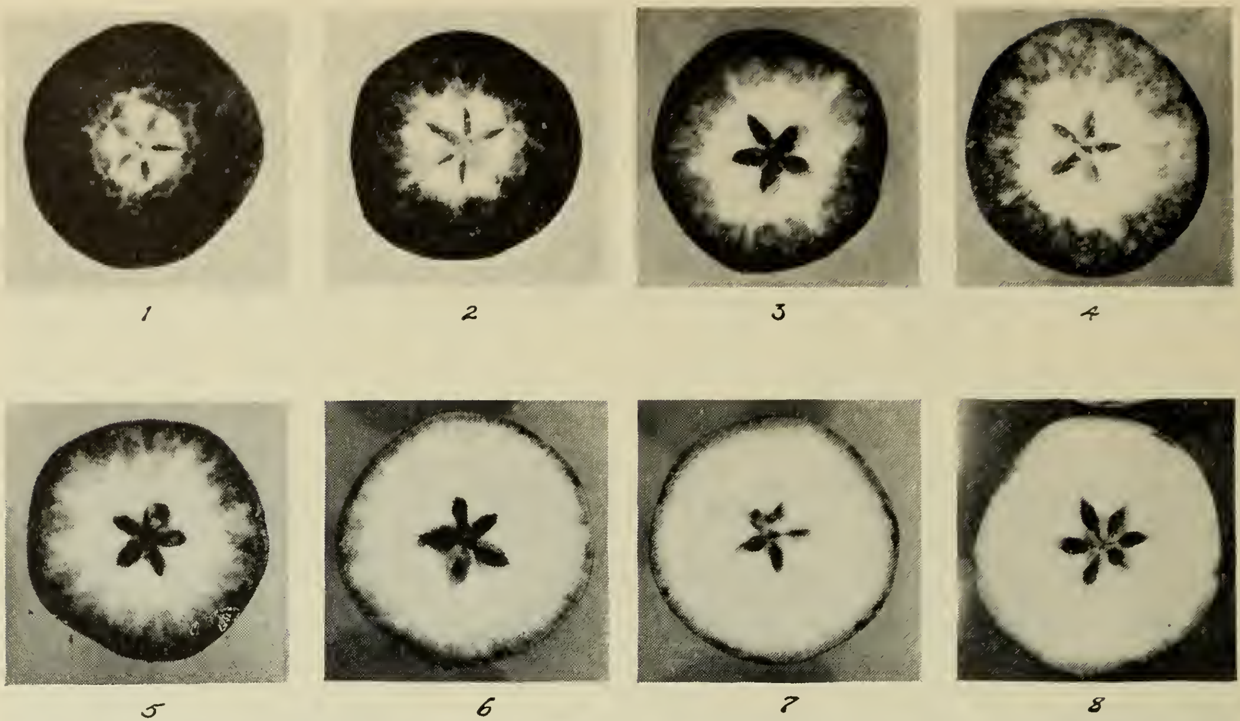


FIG. 4.—Progressive stages in starch disappearance from Delicious apples as indicated by the iodine test. Stage 1 taken at time of picking. Nos 2 and 3 are stages in ripening. At stage 4 apples are first eating ripe and become increasingly more mellow through stages 5, 6 and 7. At stage 8 fruit has become mealy.

The softening of apples as they ripen is brought about by the breaking down of the protopectin in the cell walls into soluble pectin and pectic acid. The resulting changes in hardness can be determined approximately by means of a mechanical pressure tester, providing a useful index of the progress of the storage life of the fruit.

The speed and character of the changes which take place in a ripening apple are materially affected by the temperature, humidity, and composition of the atmosphere. The influence of each of these factors is discussed in turn.

Temperature

The capacity of a refrigeration plant is commonly expressed in British thermal units or in tons of refrigeration. One B.t.u. is the amount of heat required to raise one pound of water 1°F., and there are 288,000 B.t.u. in one ton of refrigeration. When apples are brought in from the orchard, they may be at a temperature of anywhere between 40° and 70°F., and thus contain a good deal of heat. Furthermore, they also generate heat through respiration. Actually, a total of about 7 tons of refrigeration is required to reduce 1,000 bushels of apples from orchard temperature to a cold-storage temperature of 32°F., taking into account all heat gains in a storage incidental to handling. Under commercial conditions it usually takes about seven days to bring about this reduction in fruit temperature to 32°F., thus utilizing about one ton of refrigeration per day to cool this volume of fruit.

The progress of the chemical changes which proceed in an apple is greatly influenced by temperature. This fact has been demonstrated many times with apples held under ideal humidity conditions and different temperature levels. As temperature rises, utilization of sugars in respiration rises; starch digestion is speeded up; acids disappear more rapidly, and the pectic materials which cement the cell walls together dissolve at an increased rate.

Experiments have revealed that the respiration of apples is about eight times as great at 60°F. as at 32°F., which suggests that the apples live about eight times as "fast" at living-room temperatures as they do in cold storage. This

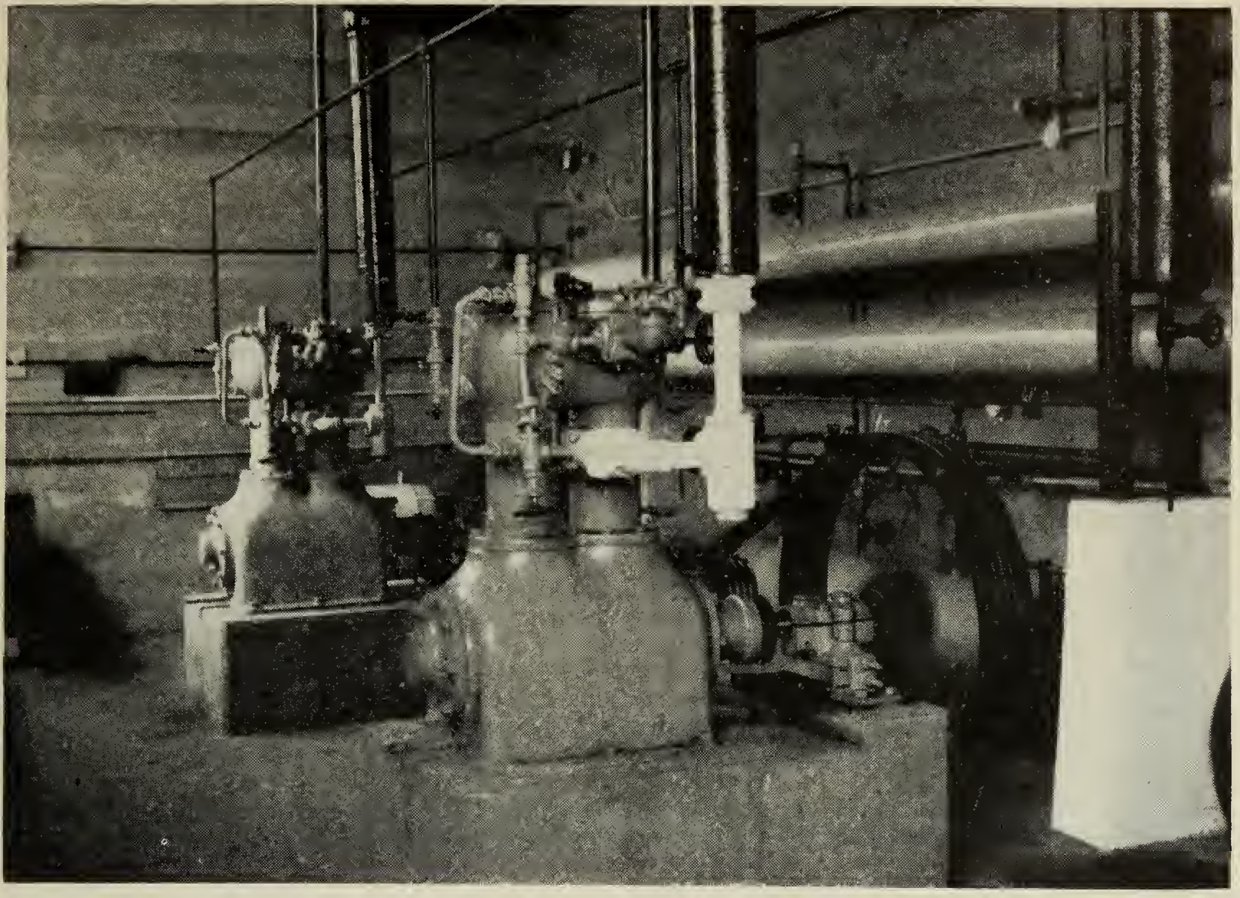


Fig. 5.—A cold storage compressor room. Compressors in front and condensers and liquid receiver at rear.

contention is substantiated by the fact that apples have been found to soften as much in twelve days at living-room temperatures as they do in four months in 32°F. storage. Thus the life of most varieties of apples can be greatly prolonged by storing them at low temperatures.

Low temperature storage has another very important beneficial effect, in that it retards and, in many cases, prevents the growth of rot-producing fungi. In this connection, storage at 30° to 31°F. is much more effective than storage at 36°F. Furthermore, the shorter the delay between harvest and cold storage of the fruit, the greater is the effect of low temperatures in preventing rots caused by fungi.

The ideal temperature at which to store apples differs somewhat with the variety. Thus Delicious and Winesap usually give excellent results when stored at 30° to 31°F., whereas Wealthy and Jonathan sometimes suffer from soft scald when held at these temperatures. On the other hand, Newtown and Northern Spy develop less bitter pit when stored at 30° to 31°F. than when stored at higher temperatures.

The temperature which apples can withstand without injury is also influenced by the conditions under which the fruit is grown. For instance, McIntosh from trees which have received heavy applications of nitrogen are susceptible to early development of core flush, when stored at 30° to 31°F., whereas fruit of this variety from trees receiving normal nitrogen applications can be stored at 30° to 31°F. until Christmas without fear of serious injury from this disorder. Similarly, apples from young trees and trees carrying light crops are especially susceptible to low-temperature disorders such as soft scald and soggy breakdown.

The problem is further complicated by the fact that maturity of fruit, when harvested, affects the resistance of apples to low temperatures. For example, McIntosh picked in an immature condition are likely to develop core flush when stored at 30° to 31°F.; whereas fruits of this variety picked at the proper stage of maturity are less susceptible to core flush, regardless of the storage temperature to which they are subjected.

Still another factor of importance in connection with low-temperature disorders is the promptness with which the fruit is placed in cold storage. Thus a delay of a week at orchard or packing house temperatures makes McIntosh quite resistant to core flush, but renders Wealthy and Jonathan subject to soft scald. Similarly, a delay of a week or two at temperatures of about 60°F., prior to 31°F. storage, tends to make Golden Delicious and Grimes Golden susceptible to soggy breakdown. In fact, soft scald and soggy breakdown rarely develop in apples placed in 30° to 31°F. storage within four days of harvest.

Apples are rarely affected with low-temperature disorders when stored at 36°F., regardless of variety, the conditions under which they are grown, the stage of maturity at which they are picked, or the promptness with which they are placed in cold storage.

The fact that the most effective means of preventing soggy breakdown and soft scald is to store the fruit at 36°F., instead of 30° to 31°F., suggests that in districts where losses from these disorders are serious, it might appear desirable to store susceptible varieties in separate rooms maintained at 36°F. However, with the central cooling air-circulation system of refrigeration used in all British Columbia apple storages, maintenance of individual rooms in the same house at different temperatures presents practical difficulties, since all rooms are supplied with cold air at the same temperature. In the autumn when large volumes of fruit are being moved rapidly into storage, this delivery temperature may be as low as 26°F., while the room temperature in certain areas may go as high as 36°F. In these circumstances the practical procedure is to avoid placing varieties such as Wealthy and Jonathan, which are subject to low-temperature disorders, near the delivery ducts. If care is taken to stack these varieties near return air paths and openings, the apples will be less exposed to low temperatures which cause injury to them.

Even when varieties such as Winesap and Delicious, which are resistant to low-temperature disorders, are placed near down-throw delivery ducts, it is important to protect the fruit from direct exposure to the cold air. Unless proper precautions are taken, fruit stacked in the direct path of discharge air may be actually frozen.

Apples in transit from cold storage to consuming markets can be maintained at temperatures between 32° and 40°F., by means of modern ships and railway cars equipped with refrigeration and heating equipment. Accordingly, apples can be shipped for long distances under favourable temperature conditions. Large markets and distributing centres are also equipped with cold storage space, but when the fruit reaches the retail fruit distributor it is commonly subjected to comparatively high temperatures.

Unlike pears, which develop maximum quality only when ripened at temperatures between 60° and 70° F., apples attain their full flavour under cool conditions. In fact, most varieties soon lose their crisp freshness when brought into a warm room. Special efforts should therefore be made to educate retail dealers and consumers to keep apples in a cool place.

Humidity

The humidity or moisture content of the storage atmosphere has a direct effect on the moisture lost from apples. If this loss of moisture is great, it causes the fruit to become tough in texture and shrivelled in appearance. On the other hand, very damp air favours the growth of moulds and rot-producing fungi. Accordingly, it may be well to consider what is meant by atmospheric humidity and how it is measured. A given volume of air at a given temperature can hold only a given quantity of moisture even when in contact with a surface of water. However, if this same volume of air is heated, its moisture-holding capacity is greatly increased. Thus at 64° F., air can hold about four times as much water vapour as at 32° F. When a volume of air is carrying all the moisture it can hold at a given temperature, it is said to be saturated. The amount of moisture in the air, in relation to the amount it would carry if saturated, is expressed as "relative humidity". For example, if the air in a storage room is carrying only 85 per cent of the moisture it would carry if saturated at that temperature, it is said to have a relative humidity of 85.

When two bodies of air of different relative humidity are brought into contact, there is a tendency for their water contents to equalize. In this connection it may be well to point out that an apple has numerous air holes or lenticels scattered over its skin. These lenticels serve as a means for inward diffusion of oxygen and outward diffusion of carbon dioxide, in the process of respiration; but they also provide points of contact between the storage air and the saturated air in the intercellular spaces of the apple tissue. The tendency of the moisture content of these two atmospheres to equalize, results in a movement of moisture from the apple to the storage air, unless this air is also saturated; and the drier the storage air, the more rapid is the loss of water from the apple.

Experiments have shown that a relative humidity of 80 to 90 in the storage atmosphere is adequate to prevent excessive shrivelling, and at the same time does not unduly encourage the growth of rot-producing fungi.

Relative humidity can be very easily measured by means of such simple instruments as the human hair hygrometer, sling psychrometer or plastic diaphragm hygrometer which are illustrated in Figure 6.

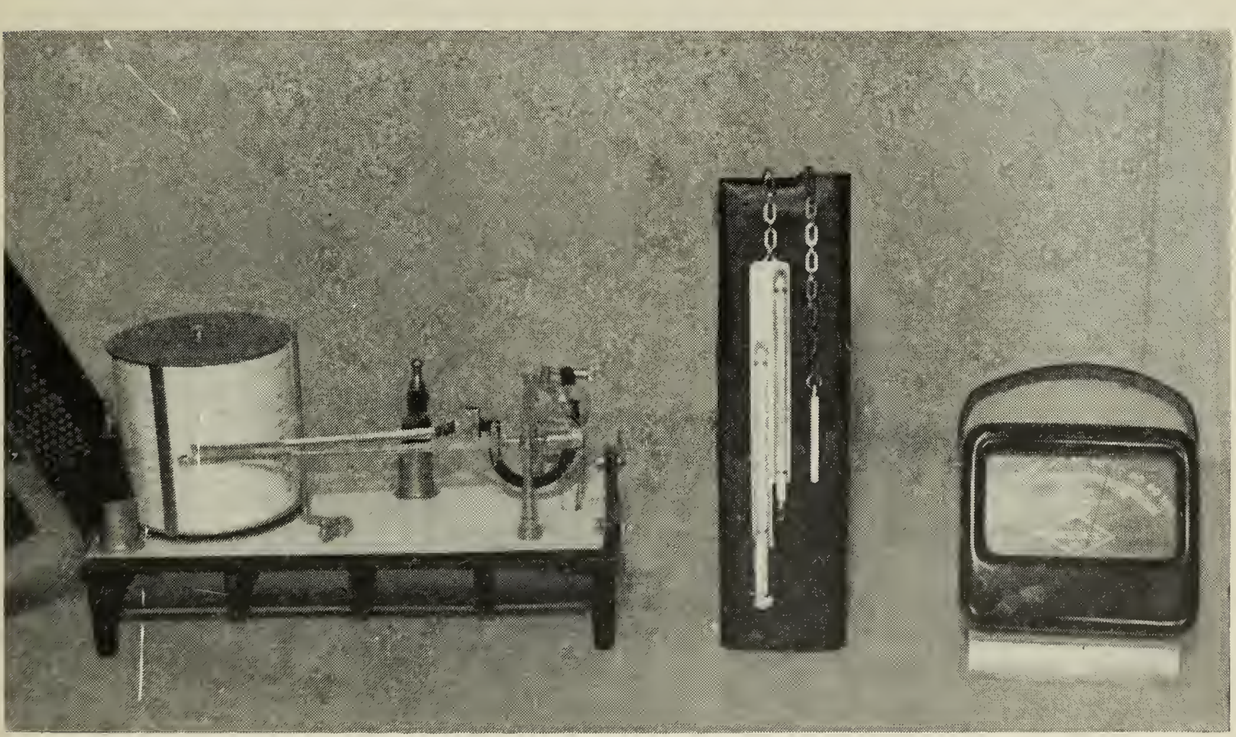


FIG. 6.—Three kinds of humidity measuring instruments: Left, human hair recording hydrothermograph, Centre, pocket model wet and dry bulb sling psychrometer, Right, moisture-sensitive plastic diaphragm indicator.

The hydrothermograph is recommended where a continuous accurate humidity record is required. The plastic diaphragm recorder has an accuracy within 1·5 per cent, is readily portable, and in an air stream, quickly comes to equilibrium. The sling psychrometer, if carefully handled, will give fairly accurate readings, but with ordinary handling is not too accurate and is somewhat inconvenient to use. The hydrothermograph is the most expensive of the three instruments and the sling psychrometer the least expensive. For general use the plastic diaphragm indicator is probably to be preferred.

The mechanism of the human hair hygrometer (humidity recording part of hydrothermograph) depends on the expansion and contraction of a strand of human hair with variations in atmospheric humidity. The degree of tension on the strand of hair is transmitted through suitable leverage to an indicating needle on a chart which records relative humidity. The sling psychrometer consists of two thermometers placed side by side on a compact metal mounting. The bulb of one is enclosed in a wick, moistened with distilled water, whereas the other is left dry. Evaporation of moisture from the damp wick lowers the temperature of the bulb within it, causing the wet bulb thermometer to give lower reading than the dry bulb thermometer. The drier the air, the greater is the difference between the readings of the two thermometers. In order to transmit rapidly to the wet bulb thermometer the cooling effect of the evaporation characteristic of the degree of saturation of the surrounding air, the two mounted thermometers are whirled through the air for a short period of time until steady readings are obtained on both thermometers. A minute or two, at most, is usually adequate to get constant readings. The thermometers should then be read rapidly, taking care to avoid contact with warm breath or warm hands.

The relative humidity of the air can then be ascertained by reference to the relative humidity table, given in Table 3. Locate at the left-hand margin of the table the figure corresponding to the dry bulb reading. Locate at the top of the table the figure corresponding to the difference between the dry and wet bulb readings. The figure at the intersection of these two columns indicates the relative humidity.

TABLE 3.—RELATIVE HUMIDITY TABLE

Dry bulb thermometer	Difference in reading between wet and dry bulb thermometers °F.																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
°F.																		
26	88	75	64	52	40	29	18	7	1	0	0	0	0	0	0	0	0	0
28	88	77	66	55	44	33	23	12	2	0	0	0	0	0	0	0	0	0
30	89	78	68	57	47	37	27	17	8	0	0	0	0	0	0	0	0	0
32	90	79	69	60	50	41	31	22	13	4	0	0	0	0	0	0	0	0
34	90	81	72	62	53	44	35	27	18	9	1	0	0	0	0	0	0	0
36	91	82	73	65	56	48	39	31	23	14	6	0	0	0	0	0	0	0
38	91	83	75	67	59	51	43	35	27	19	12	4	0	0	0	0	0	0
40	92	84	76	68	61	53	46	38	31	23	16	9	2	0	0	0	0	0
42	92	85	77	70	62	55	48	41	34	28	21	14	7	0	0	0	0	0
44	93	85	78	71	64	57	51	44	37	31	24	18	12	5	0	0	0	0
46	93	86	79	72	65	59	53	46	40	34	28	22	16	10	4	0	0	0
48	93	87	80	73	67	60	54	48	42	36	31	25	19	14	8	3	0	0
50	93	87	81	74	68	62	56	50	44	39	33	28	22	17	12	7	2	0
52	94	88	81	75	69	63	58	52	46	41	36	30	25	20	15	10	6	0
54	94	88	82	76	70	65	59	54	48	43	38	33	28	23	18	14	9	5
56	94	88	82	77	71	66	61	55	50	45	40	35	31	26	21	17	12	8
58	94	89	83	77	72	67	62	57	52	47	42	38	33	28	24	20	15	11
60	94	89	84	78	73	68	63	58	53	49	44	40	35	31	27	22	18	14
62	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29	25	21	17
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31	27	23	20
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28	24
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35	32
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37	34
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38	35

In cold storages using the brine spray system of refrigeration, humidity of the atmosphere is influenced by temperature and concentration of the brine and the amount of air driven through it. In general, running cold storage compressors at suction pressures not lower than those stipulated in the dealers' contract, and maintaining brine strengths at levels just sufficient to prevent frosting of coils, results in satisfactory humidity conditions.

Provision of favourable humidity conditions, after apples are removed from storage, presents more difficult problems. When apples are first removed from low to high temperatures, they often become covered with free moisture and are said to "sweat". What actually happens is that the warm air near the cold apples is suddenly cooled down, with the result that it becomes supersaturated with moisture which condenses on the cold fruit. Such conditions are favourable to rot-producing fungi, particularly where stem punctures are prevalent. This tendency of fruit to sweat, when removed to a warmer temperature, constitutes an objection to the practice of placing apples loose in cold storage prior to packing at a later date. However, loose storage of apples is unavoidable in the season of peak deliveries, where grader equipment cannot cope with the heavy daily intake of fruit.

A totally different problem is presented by the dry atmospheres commonly encountered in retail stores and consumers' homes. When subjected to these conditions, apples tend to shrivel and lose their freshness. This tendency has been checked experimentally, by covering the fruits with a very thin film of wax emulsion before packing. This procedure partially closes some of the lenticels in the skin, and checks the loss of water from the fruit. Unfortunately the application of wax to apples has sometimes had undesirable effects on the storage life of the fruit, with the result that the waxing process has not been accepted by the apple industry. Of prime importance is the necessity for drawing to the attention of distributors and consumers, the fact that apples retain their appetizing flavour, aroma, and crispness to the greatest extent when they are kept in a cool damp atmosphere.

Ventilation

In common storage warehouses, ventilation is necessary for regulating temperature. At the same time, ventilation also removes excess humidity and by-products of respiration. These by-products of respiration include carbon dioxide, acetaldehyde, ethylene and aromatic esters. In refrigerated warehouses, operated under closed circuit forced air circulation, however, ventilation with outside air is seldom practical.

For best results with common storage, adequate ventilation is essential. For every 3,000 cubic feet of storage space, there should be a cold-air inlet 3 feet long by 18 inches high, and a warm-air outlet of about the same dimensions. The fruit should be stacked on a slatted false floor, built a foot or so above the floor proper, and air spaces should be left between the piles of boxes. The cold air inlets should be located so as to deliver fresh air below the slatted floor, from which it can pass up through the fruit and out the ventilators in the roof. In bank cellars, the vents may be left open day and night during the autumn months. In above-ground storages, the vents should be opened only when the outside temperature is lower than the storage air. What is more effective, of course, in cooling common storage fruit is to install an electrical fan unit in the warm air outlet capable of changing the air in the storage once in every 7 to 10 minutes.

If apples are held for a time in receiving and packing rooms, which are not equipped with ventilation systems, it is advisable to open doors and windows at night to facilitate free movement of air through the fruit. The movement of air may be accelerated by the use of fans. Adequate ventilation helps to cool the fruit and also carries off the gases, which, if left to accumulate in close contact with the apples, may cause scald. These gases are produced most rapidly during the first month after the fruit is picked. It is therefore very important that adequate ventilation be given during the autumn months.

In a building equipped with refrigeration, the air in the storage rooms is usually chilled by recirculating it through a brine spray or over dry coils with a central fan. This practice keeps the air in continuous motion. There is usually sufficient fresh air introduced through the doors and ports used for moving the fruit in and out of storage, to prevent undue accumulation of toxic products in the storage atmosphere. Moreover, the almost universal use of oiled wraps gives excellent adsorption of gases causing scald. If it is considered advisable to introduce additional fresh air, care should be taken to pass this through the cooling chamber to ensure that it enters the storage rooms at the proper temperature and humidity.

Gases Produced by Apples

Carbon dioxide is a product of respiration and is produced freely by apples. This gas is not toxic to the fruit unless present in high concentrations. There are records of carbon dioxide causing a disorder known as "brown heart", in apples transported for long voyages in the unventilated holds of ships. However, the low concentrations of carbon dioxide, commonly experienced in apple storage houses, actually tend to prolong the life of the fruit.

Acetaldehyde is a by-product of respiration and is considered by some to be a contributory cause of apple scald. It is also possible that low-temperature disorders such as soggy breakdown and core flush are due, at least in part, to increased production and accumulation of this gas.

Ethylene is a volatile product given off by apples during the period of rapid respiration, which usually occurs shortly after harvest. The exposure of unripe fruit to ethylene, or emanations from ripe fruit, has been shown to hasten ripening. Both the presence of ethylene and the conditions suitable for ethylene production appear necessary for normal ripening. Ethylene from ripe fruit may accumulate in a storage, to such a concentration that unripe fruit may thereby be stimulated. This could occur at any temperature, although 30° to 32°F. storage reduces ethylene production of apples to a minimum, and similarly reduces its stimulating effects upon unripe fruit.

Air Purification

Removal of ethylene and other harmful gases from the storage atmosphere presents a practical problem in prolonging the life of stored fruit. Ventilation of cold storages with fresh air is not practical, particularly when outside temperatures are relatively high. Activated carbon air filters, which have been used in an attempt to remove harmful volatiles from the storage air, have proven effective in odour control but only slightly effective in reducing the ethylene concentration. Segregation of early and late varieties in the storage might be helpful, but is not always possible. For the present, until more data are available, it would appear that the safest procedure to guard against the harmful effects of ethylene in storages, is to place apples in cold storage within 48 hours of harvest, and to reduce them to a core temperature of 30° to 31°F. as rapidly as possible.

Controlled Atmosphere Storage (Gas Storage)

In recent years a great deal has been written about gas storage of apples. The idea originated in England about 25 years ago following the work of Kidd and West with certain English apples, notably the culinary variety, Bramley Seedling. By storing this variety at 40°F. in atmospheres containing around 8 per cent carbon dioxide with reduced oxygen, a keeping life equal to that at 32°F. was obtained, but with the elimination of core browning usually occurring at the lower temperature. Subsequent work with Cox Orange, Lane's Prince Albert and other English varieties showed that artificially controlled atmospheres added to commercial keeping life. The possibility of lengthening the keeping life of American and Canadian grown varieties, by means of controlled atmosphere storage, has received considerable attention. The term "gas storage" was perhaps an unfortunate name to apply to the storage of apples held under modified carbon dioxide-oxygen atmospheres; and so to eliminate the sinister implications of this expression, North American investigators have agreed to define the process more accurately as "controlled atmosphere storage".

The principle of controlled atmosphere storage centres around the process of respiration in fruit. All fruit, both before and after harvest, carries on respiration in a manner somewhat similar to respiration in animals. This process involves the oxidation of sugars to produce energy. In so doing, oxygen is absorbed and carbon dioxide is liberated. Under conditions of normal ventilation in a conventional storage, the deficit of oxygen and corresponding increment of carbon dioxide are scarcely detectable, owing to replacement of oxygen from, and diffusion of carbon dioxide to, the outside air.

If, however, fruit carries on respiration in an air-tight compartment or room, the normal 21 per cent oxygen content of the air becomes depleted, and the very small (less than one per cent) carbon dioxide content of the air is correspondingly increased. Thus, if oxygen is reduced by 10 per cent, carbon dioxide is raised by 10 per cent. With most varieties of apples, as oxygen is decreased and carbon dioxide increased, the resulting effect upon the fruit is a slowing down of the respiration process, and with it a similar reduction in rate of softening of the flesh. Since varieties such as McIntosh, when stored for prolonged periods at 30° to 31°F., tend to develop a low temperature injury around the core known as core flush, there has been considerable interest in controlled atmosphere storage for this variety. While results indicate that McIntosh stored at 40°F. in 7 per cent carbon dioxide and 14 per cent oxygen keep as well as air-stored apples at 32°F., and do not develop core flush, another type of injury has been found, particularly in less mature fruits, which shows as a rough wrinkled skin scald.

Another set of controlled atmosphere conditions involving very low oxygen content of storage air (2·5%) plus 5 per cent carbon dioxide at 40°F., have also been found to extend storage life of McIntosh apples. Experimental storage of Delicious apples at 32° F., in atmospheres of 2·5 per cent oxygen or under 2·5 per cent oxygen plus 5 per cent carbon dioxide, has resulted in fruit of improved firmness and quality when removed from cold storage. However, the mechanical aspects of producing these atmospheres on a large scale present difficulties; and improvement in keeping quality of apples, subsequent to removal from controlled atmosphere storage as compared with air storage, is not so marked as the differences at time of removal would suggest. As far as the McIntosh and Delicious varieties are concerned, experiments conducted at the Summerland Station indicate that controlled atmosphere storage on a commercial scale would not be a practical procedure, in view of the cost of adapting present cold storages and the various mechanical problems that would arise. Considerable effort has been made in the eastern United States to stimulate interest in commercial application of controlled atmosphere storage for McIntosh, but with limited acceptance.

On the other hand, there is one fruit that seems to respond very well to controlled atmosphere storage and that is the Bartlett pear. Held at 32°F. under 7 per cent carbon dioxide and 14 per cent oxygen, its normal keeping life can be doubled. If present pear tonnages continue to increase, there is a possibility that controlled atmosphere storage of Bartlett pears on a limited scale might assume commercial importance.

Despite popular opinion to the contrary, recent authoritative information from England indicates that not more than 2,000,000 bushels of the English apple crop are held under "gas storage".

Before leaving the subject of controlled atmosphere storage it might be well to point out some mechanical reasons why this treatment is not likely to prove practical for the British Columbia apple cold storage industry. The first reason is that B.C. fruit cold storages are constructed for cooling produce by means of a central system of forced air circulation with one central fan and evaporator coil in each building. These buildings consist of one or more floors and the storage capacities vary from 10,000 to 290,000 boxes. These rooms would have to be subdivided into small rooms of around 20,000 box capacity, and the central air distribution system scrapped and in its place small evaporator coils and fans placed in each room.

The next step would be an expensive and exacting job of "gas-tighting" each room so that when the room is loaded it may be sealed up to permit a certain gas mixture to be maintained. For each individual room, controls would have to be mounted externally for gas sampling, temperature recording and control over the refrigerating unit.

A further disadvantage of controlled atmosphere storage is that the concentrations of carbon dioxide required are injurious to human beings, with the result that storage rooms cannot be entered at will to take out varieties, sizes, or grades required for shipment. All the apples to be held in any one storage chamber must be put in at one time and the room kept sealed until it is decided to market the contents, at which time it is thoroughly ventilated before allowing workmen to enter. After a controlled atmosphere storage chamber has been opened, it can of course be continued in operation as an ordinary cold storage room.

Storage Life of Different Varieties

Even when apples have been grown under favourable conditions, picked at the proper stage of maturity, and given satisfactory storage treatment, their possible storage life is limited by characteristics inherent in each variety. As a general rule, apples which mature early in the season ripen rapidly and are not suited for long storage. Furthermore, even the late-maturing varieties with good keeping qualities have definite storage limits after which they lose their characteristic aroma, flavour, and texture. Sometimes the internal condition of the fruit deteriorates, while the outward appearance is still satisfactory. For instance, McIntosh apples removed from 31°F. storage in April may have as good appearance as when they were picked, but when such fruits are cut open they usually show severe core flush, lack aroma and varietal character, and may even be disagreeable in flavour. If apples are kept too long in either common or cold storage, they eventually succumb to some disorder such as mealy breakdown or rot.

In commercial practice, apples should be removed from common or cold storage some time before they have reached the end of their prime storage life, in order that they may have time to pass through the regular channels of trade and still reach the consumer in good condition. Allowance should be made for a period of at least two weeks to deliver apples from the storage house to the consumer.

Apple varieties may be divided into four groups according to the season in which they are in best eating condition. Early-maturing varieties of short-storage life, such as Yellow Transparent and Duchess, may be classified as summer apples. Wealthy and Cox Orange may be considered fall apples; McIntosh, Jonathan and Delicious early winter apples; and Newtown, Rome, Stayman and Winesap late winter varieties.

Cold storage facilities make it possible to prolong materially the marketing period for all varieties, but in most cases their relative season remains the same. Thus the marketing season for McIntosh, originally considered a fall apple, has been lengthened by cold storage, with the result that this variety can now be delivered to consumers in good condition up to the end of December.

In order that the British Columbia apple crop may be marketed to best advantage, it is imperative that special care be taken to ensure that the fruit reaches the consumer in good condition. This involves segregation and early disposal of apples from young and light-crop trees. It also involves frequent inspection of storage stocks and prompt sale of "weak" lots of fruit which show signs of early ripening or wastage.

Most important of all, varieties should be offered for sale during their period of prime quality, and not a month or so later after their characteristic flavour and texture have started to deteriorate. The following table indicates the usual storage period at 30° to 31° F. during which different varieties retain their optimum quality. If removed from cold storage within these prescribed limits and disposed of within a reasonable time, the consumer should receive an apple of satisfactory quality.

TABLE 4.—USUAL PRIME STORAGE LIFE OF DIFFERENT VARIETIES OF APPLES AT 30° TO 31° F.

Variety	*Storage Period*
McIntosh	December 31
Jonathan	December 31
Spartan	January 15
Jubilee	February 1
Golden Delicious	February 1
Delicious	February 15
Rome	March 15
Stayman	April 15
Winesap	April 15
Newtown	April 15

STORAGE DISORDERS OF APPLES

The susceptibility of apples to storage disorders is influenced by variety, by the conditions under which the fruit is grown, by the stage of maturity at which it is picked, and by the storage treatment which it receives. In order that losses from these disorders may be reduced to a minimum it is essential that growers, storage-house operators, and fruit distribuors be familiar with the nature of the injuries and means of controlling them. A number of storage disorders which have been encountered from time to time in British Columbia-grown apples are described and illustrated in the following pages. Information is presented concerning the chief causal factors and, where possible, methods of control for each disorder.

Water Core

The characteristic that distinguishes water core is the glassy, water-soaked appearance of the flesh due to filling of the intercellular spaces with cell sap instead of air. Sometimes practically the whole apple is involved, and the watery tissue is evident through the skin, but more often the disorder is confined to the tissue bordering the vascular bundles or that adjacent to the core. When Jonathan and Delicious apples are cut across, water core can often be discerned as a series of water-soaked spots arranged in a circle around the core. In advanced stages of the disorder, these spots unite to form a continuous band of water-soaked tissue. Water core is illustrated in Figure 7.

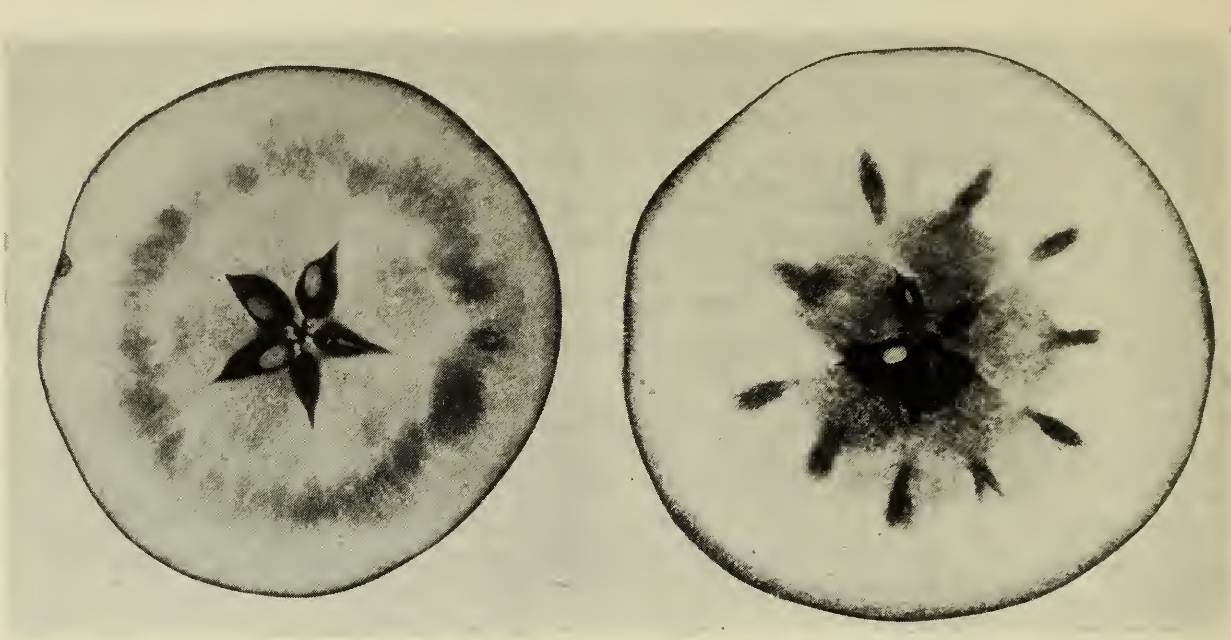


FIG. 7.—Water core in Jonathan apples. The characteristic water-soaked area around the core occurs with certain varieties as they become too mature. Slight water core may disappear in storage—more advanced water core predisposes the fruit to mealiness and breakdown.

With varieties such as Delicious and Wagener, a slight development of water core is not a serious matter because it disappears during storage, leaving the fruit apparently uninjured. However, apples seriously affected with water core usually develop breakdown. This is especially true of the Jonathan variety. Severe water core in Delicious predisposes the fruit to early development of mealiness. There is still some doubt as to the primary cause of water core. However, there is good evidence that it is not associated with over-irrigation but rather with advanced maturity and exposure of the fruit to intense sunshine. The obvious control is to harvest the apples at the proper stage of maturity.

Jonathan Breakdown

This disorder is found chiefly in the Jonathan variety but has also been observed in many other varieties such as Delicious, Stayman, and Rome Beauty. The injury seldom develops until several weeks after the fruit is picked. It is first evident as a light brown discoloration of the flesh and in this stage can only be detected by cutting the fruit. The affected areas are indefinite in outline and usually originate in the region of the vascular bundles or near the skin. In the advanced stages of the disorder affected specimens can often be identified by the dull colour of the skin and the soft spongy feeling of the fruit.

Jonathan breakdown is most prevalent in fruit from young trees or mature trees carrying a light crop. However, even fruit from mature trees carrying a full crop becomes susceptible, if permitted to remain too long on the trees. Cold storage temperatures retard but do not prevent development of the disorder. Two stages of Jonathan breakdown are shown in Figure 8.

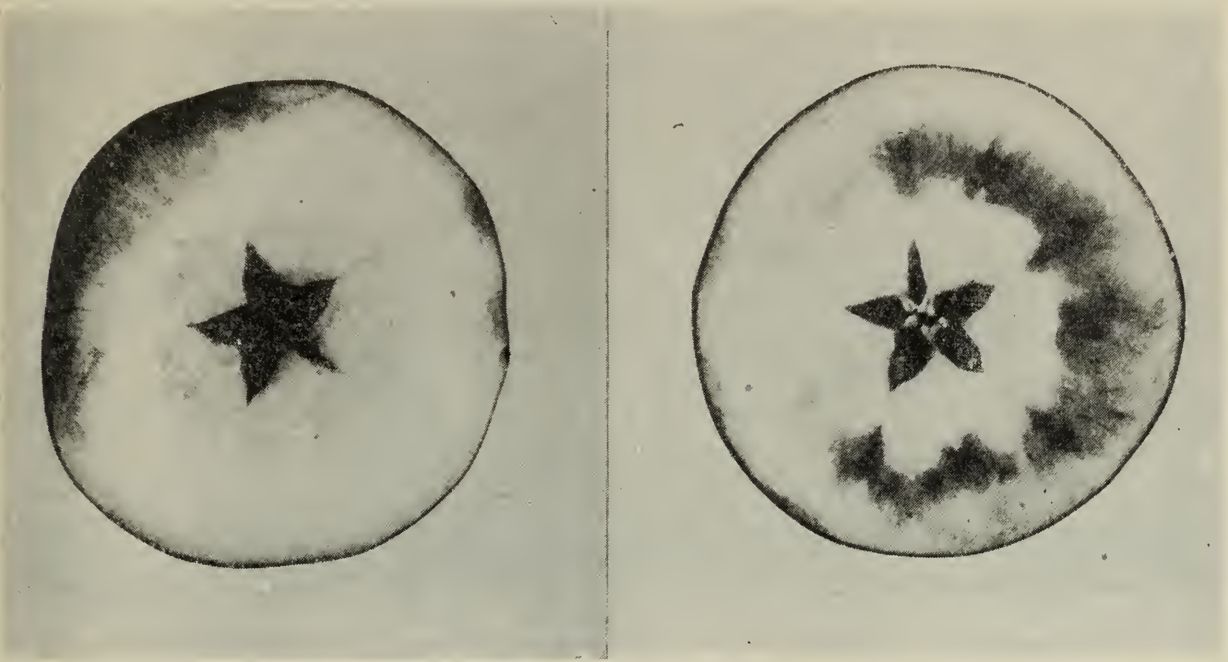


FIG. 8.—Jonathan breakdown, resulting from overmaturity and following after water core. Two common forms of the disorder are shown. Jonathan breakdown can be prevented by picking at the correct maturity as indicated by the Jonathan skin colour chart.

Losses from Jonathan breakdown can be reduced to a minimum by segregating fruit from light- and heavy-crop trees, and by harvesting all fruit at the proper stage of maturity. As a general rule, Jonathan apples from mature, full-crop trees mature in about 145 days from full bloom. To assist growers to pick their fruit at the right time, a simple skin colour maturity chart has been devised. A facsimile of this chart is shown in Figure 1.

Mealy Breakdown

This disorder is essentially an "old age" disease which develops when apples are held in storage for periods longer than their prime storage life. It is characterized by the flesh becoming dry, discoloured, and spongy. The skin often ruptures, as shown in Figure 9, thus permitting the entrance of fungi which cause the fruit to rot. Mealy breakdown is most frequently encountered in coarse-textured varieties such as Yellow Transparent, Duchess, Wealthy, McIntosh and Delicious. Mealy breakdown is serious only in fruit held too long in storage. Therefore the obvious control is to market each variety during its proper storage season.

Soggy Breakdown and Soft Scald

These two disorders differ markedly in physical appearance, but they are usually grouped together on account of similarity of causal factors and methods of control. They are both low temperature disorders and are most serious in Jonathan, Golden Delicious, Rome Beauty, Grimes Golden and Winter Banana. While general losses from these disorders are seldom serious in fruit grown in British Columbia, nevertheless individual lots of Jonathan and Rome Beauty apples have on occasion developed severe soft scald. Soggy breakdown and soft scald are illustrated in Figure 10.

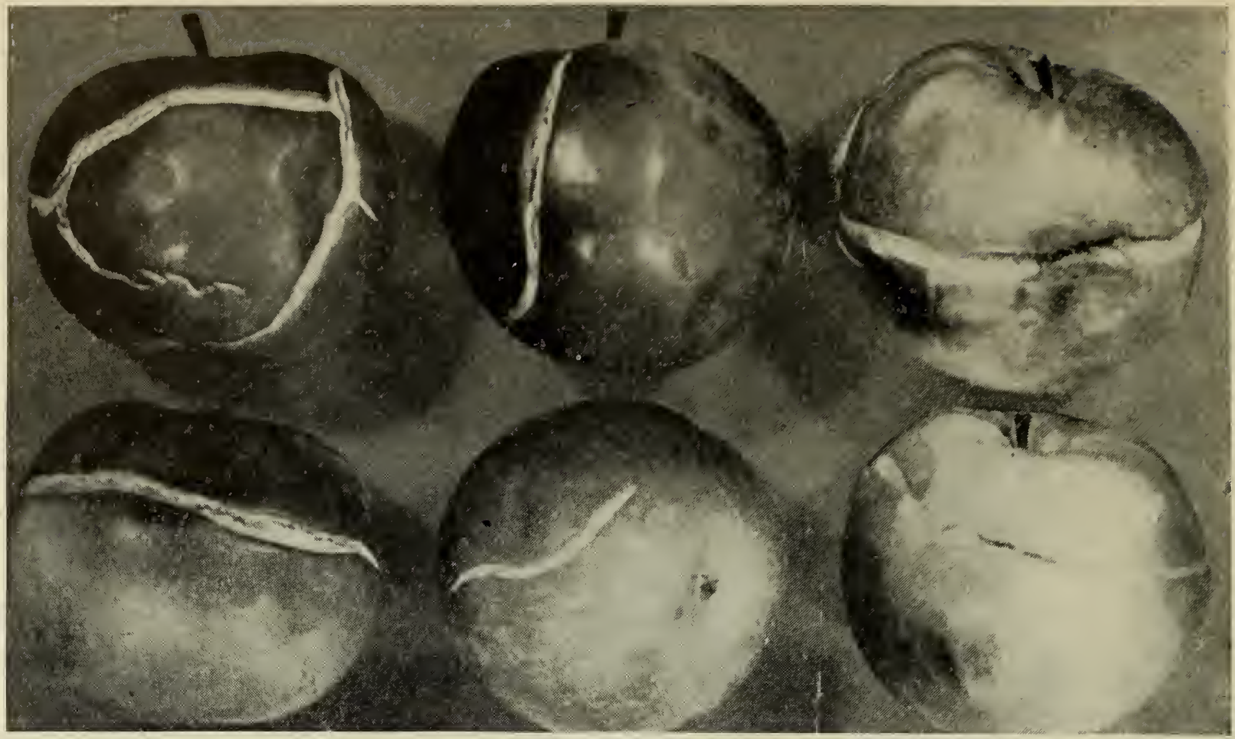


FIG. 9.—Mealy breakdown in McIntosh, advanced stage. The peculiar condition sometimes occurs in McIntosh which have been stored beyond their normal keeping life.

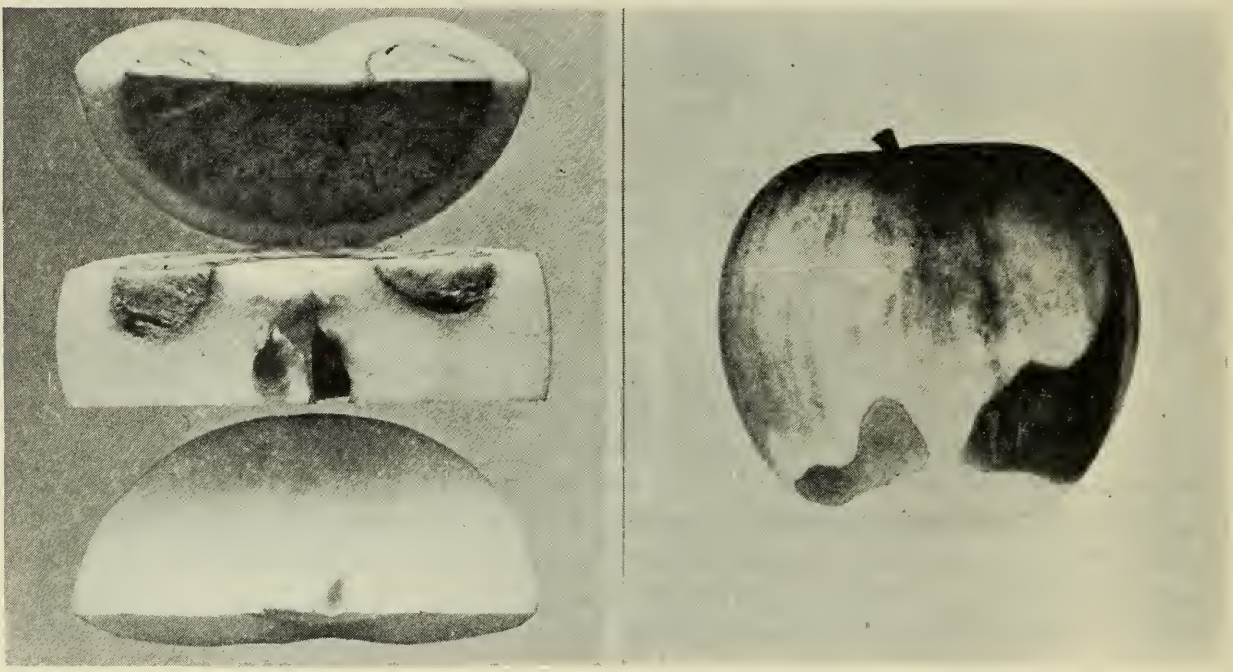


FIG. 10.—Soggy breakdown in Grimes Golden left, and soft scald in Jonathan, right. These are different manifestations of the same physiological disturbance. Soggy breakdown is aggravated by under-maturity and by placing apples at 31 deg. F. after being held at field temperatures 5 days or more after picking. Immediate storage at 30 deg. to 31 deg. F. or storage at 36 deg. F. following delayed storage, controls this disorder.

With soggy breakdown, sharply defined brown areas develop midway between the core and skin. After the fruit is removed from cold storage the affected tissue becomes dry and corky. The injured areas range in size from small pits to wide bands which sometimes encircle the core. In the early stages the injury can be detected only by cutting the fruit; but as the disorder progresses, affected specimens can be recognized by their dull colour and springy feeling.

The first symptoms of soft scald may be observed on cold-stored fruit as early as December 1, after which date the prevalence and severity of the injury increase rapidly. Sharply defined areas just below the skin turn brown and become sunken, giving the apples the appearance of having been rolled on a hot stove. The injured areas assume peculiar patterns and the underlying tissue turns brown, becoming soft and watery. The Jonathan and Rome Beauty varieties are particularly susceptible.

Development of soggy breakdown and soft scald is influenced somewhat by the conditions under which apples are grown and stage of maturity at which they are picked. Thus the disorder is more prevalent some seasons than others, fruit from certain orchards being especially susceptible and fruit picked in an immature condition being more likely to develop soggy breakdown than fruit picked at the correct stage of maturity.

Storage temperature, however, is the most important factor related to development of these disorders. Provided susceptible varieties are placed in cold storage within four days of the time they are picked, they usually withstand storage temperatures of 30° to 31°F. without injury, but if they are delayed at packing-house temperatures for more than four days before being cold stored, they are likely to develop soggy breakdown or soft scald when subjected to temperatures below 36°F. In some areas a temperature of 36°F. is therefore recommended for varieties such as Jonathan and Golden Delicious as a safeguard against losses from this disorder. On account of difficulties in producing a temperature of 36°F. in a storage plant run at 30° to 31°F., the most practical preventive measure is considered to be harvesting apples at proper maturity and storing them promptly at 30° to 31°F. It is especially important to avoid stacking susceptible varieties in direct contact with cold air discharged from supply ducts.

Core Flush (Core Browning, Brown Core)

These terms are used somewhat interchangeably in describing several types of tissue browning located in the core area of apples. For purposes of this discussion, however, the term "core flush" only will be used. Core flush usually starts in one of three ways: (1) as small brown areas next to the carpels, (2) as a light brown discoloration following the contour of the core line or, (3) as a lightly suffused brown flush of the tissue within the core-line. In the first case the injury extends outwards towards the core-line, in the second case inward towards the carpels, and in the third case the browning of the affected area intensifies with prolonged storage. Ordinarily, the external appearance of core-flushed apples is unaffected except for a dull browning of the skin within the stem-end cavity. Inasmuch as the brown injured area represents dead tissue, it is not surprising that apples so affected deteriorate rapidly in quality and assume a stale, aldehyde flavour. Typical core flush is illustrated in Figure 11.

Core flush is a low temperature disorder usually found only in fruit which has been held for long periods at temperatures under 36°F. In the fruit-growing areas of B.C., McIntosh and Newtown are the varieties most seriously affected. It is common in McIntosh held in 30° to 31°F. storage later than Christmas. Furthermore, large, poorly-coloured apples from trees which have been heavily fertilized with nitrogen are especially susceptible to core flush. Conversely, small and/or well-coloured apples show the least injury. Picking McIntosh and Newtown before they are fully mature greatly increases their susceptibility to this disorder.

When fruit is removed from cold storage to room temperature there may be no evidence of core flush. However, during a 7- to 14-day period at temperatures of 60° to 70°F., such as commonly elapses from the time the fruit leaves storage until it is eaten by the consumer, susceptible apples rapidly develop the characteristic core injury.

Development of core flush can be largely prevented, even in apples susceptible to it, by storing at 36° to 40°F., rather than at 30° to 31°F., but storage at these

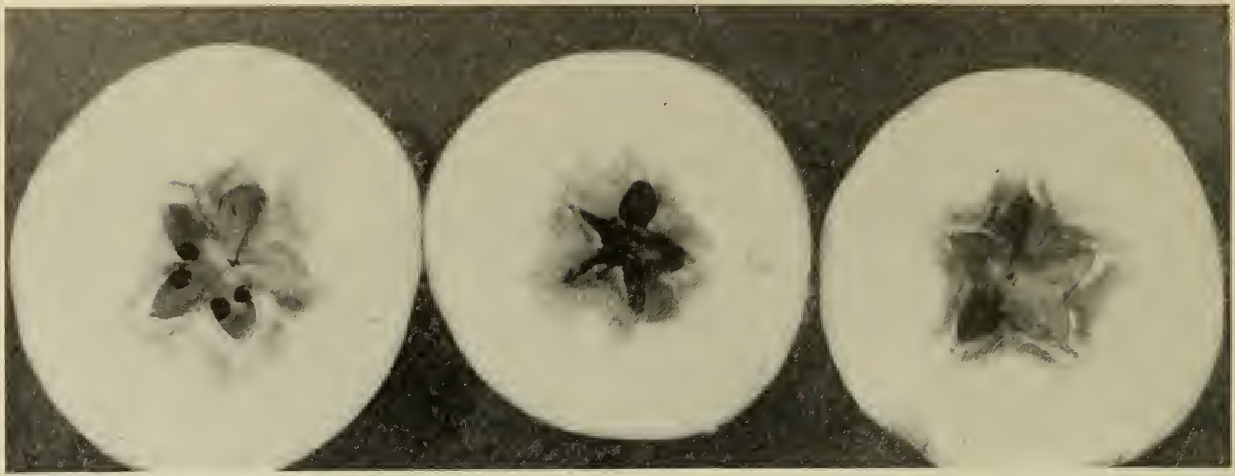


FIG. 11.—Core flush in McIntosh. This disorder is associated with three factors, immature harvesting, low temperature (30 deg. - 31 deg. F.) storage and old age. Mature McIntosh held at 30 to 31 deg. F. and disposed of before Jan. 1st seldom are seriously affected.

higher temperatures shortens the life of McIntosh. In view of the importance of keeping McIntosh in as firm a condition as possible until they are offered for sale, storage temperatures of 36° to 40°F. cannot be recommended—but rather, prompt storage at 30° to 31°F. within 48 hours of picking. Where McIntosh are held in storage at 30° to 31°F. not later than Christmas, the fruit retains a maximum of appearance and quality and usually develops a minimum of core flush. McIntosh stored later than Christmas are extremely susceptible to core flush.

The extent of core flush development in McIntosh has been found to vary considerably from season to season, from area to area, and from tree to tree in the same orchard. While these differences are recognized, no fully satisfactory explanations have been advanced for them.

Apple Scald

Apple scald is a disorder which occurs frequently on a great many varieties of apples. In some seasons it is markedly prevalent, and in others causes little damage. The disorder is characterized by browning of the skin. In some cases browning may be so slight as to be hardly noticeable, while in others the apples may be so disfigured as to render them worthless. Severe scald is shown in Figure 12. Apple scald develops more slowly at 32°F. than at higher temperatures. Apples which appear normal at time of removal from cold storage often develop a serious amount of scald within a period of one day to two weeks from time of removal to room temperature.

With Grimes Golden and Newtown, scald may cause heavy losses because the injury is so evident on the yellow skins of these varieties. With the Wagener variety, the injury sometimes extends into the flesh causing a condition similar to Jonathan breakdown.

On red-skinned varieties such as McIntosh, Delicious and Winesap, the disorder ordinarily becomes evident only on the unblushed portion of the apples. Fruits picked in an immature condition and carrying a good deal of unblushed surface are most susceptible. Sometimes even a well-matured fruit will, toward the end of the storage season, develop a mahogany tint to the skin colour which seems to be another form of scald. The fruit is neither affected in eating quality, nor is its appearance seriously impaired, but instead of having a bright red lustre it takes on a dullish colour.

Most varieties of apples when picked at the correct stage of maturity develop little or no scald, but when picked two, or even one week immature, are

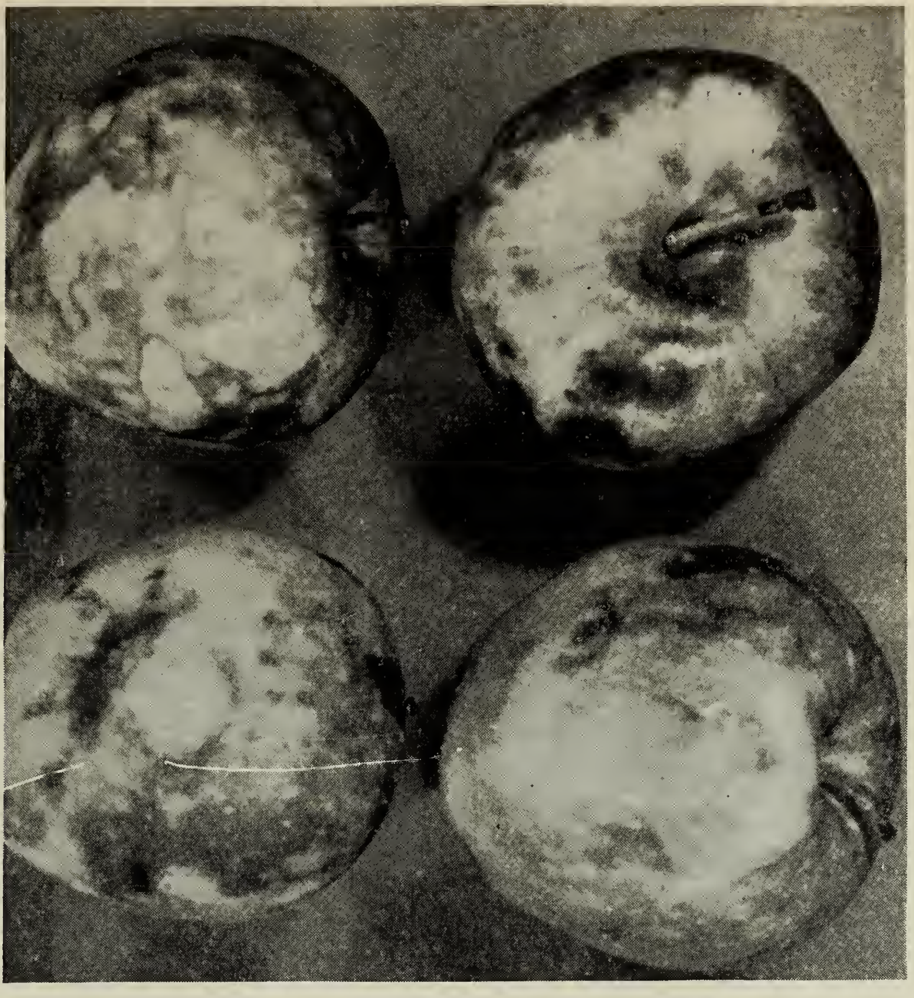


FIG. 12.—Apple scald on Delicious. The disfiguring brown blotches result primarily from immature harvesting, but the disorder may be controlled by use of oil-impregnated wraps, provided fruit is wrapped within several weeks of harvest.

likely to develop a serious amount of this disorder. The exact cause of storage scald is not definitely known but it is associated with the accumulation of acetaldehyde in the affected areas.

Until about 1920 apple scald annually caused heavy losses. At this time it was discovered that ordinary sulphite paper wraps impregnated with 15 to 20 per cent mineral oil gave commercial control of the disorder. As a result, the entire B.C. apple crop except McIntosh is now packed in oiled paper, which gives control of scald on most varieties. With Newtown, results are usually, but not always, satisfactory; and with Delicious picked in an immature condition, appreciable amounts of scald may develop even though oiled wraps are used.

The beneficial effects of oiled wraps in controlling scald are attributable to the adsorption by the oil of deleterious gases given off by the fruit. To be effective in scald control, the oiled paper must be applied shortly after the fruit is picked. Oiled wraps are specifically of value only in the control of scald, and do not have any marked effect upon disorders such as breakdown, bitter pit, or Jonathan spot. Since the physiological injury responsible for development of scald takes place during the first 6 to 8 weeks of storage, the use of oil wraps in wrapping apples which have been stored loose for several weeks is of doubtful value.

Other treatments such as storage of apples in air purified by passing it through activated carbon canisters, and exposure of apples to high concentrations of carbon dioxide for several days before storage have given control of scald on an experimental basis. However, on a commercial scale, adsorption of scald gases by activated carbon has given barely as good results as oiled wraps, and the use of high concentrations of carbon dioxide is impractical on account of the extra expense involved in handling the fruit and gas-tighting the carbon dioxide rooms.

Bitter Pit

Bitter pit is usually characterized by sunken, circular or nearly circular spots on the surface of the apple which extend into the flesh as brownish pits of dead tissue. These pits vary considerably in size. They are usually more prevalent towards the calyx end of the fruit. The pits are not always evident from the exterior but they seldom extend more than half an inch into the flesh. With the Newtown variety (see Figure 13), the pits are sometimes deep seated, resembling internal cork, a deficiency disease caused by lack of boron in the soil. However, applications of boron have had no influence on the control of bitter pit. Typical bitter pit may occur on apples while they are still on the tree, but more often develops shortly after the fruit is picked.

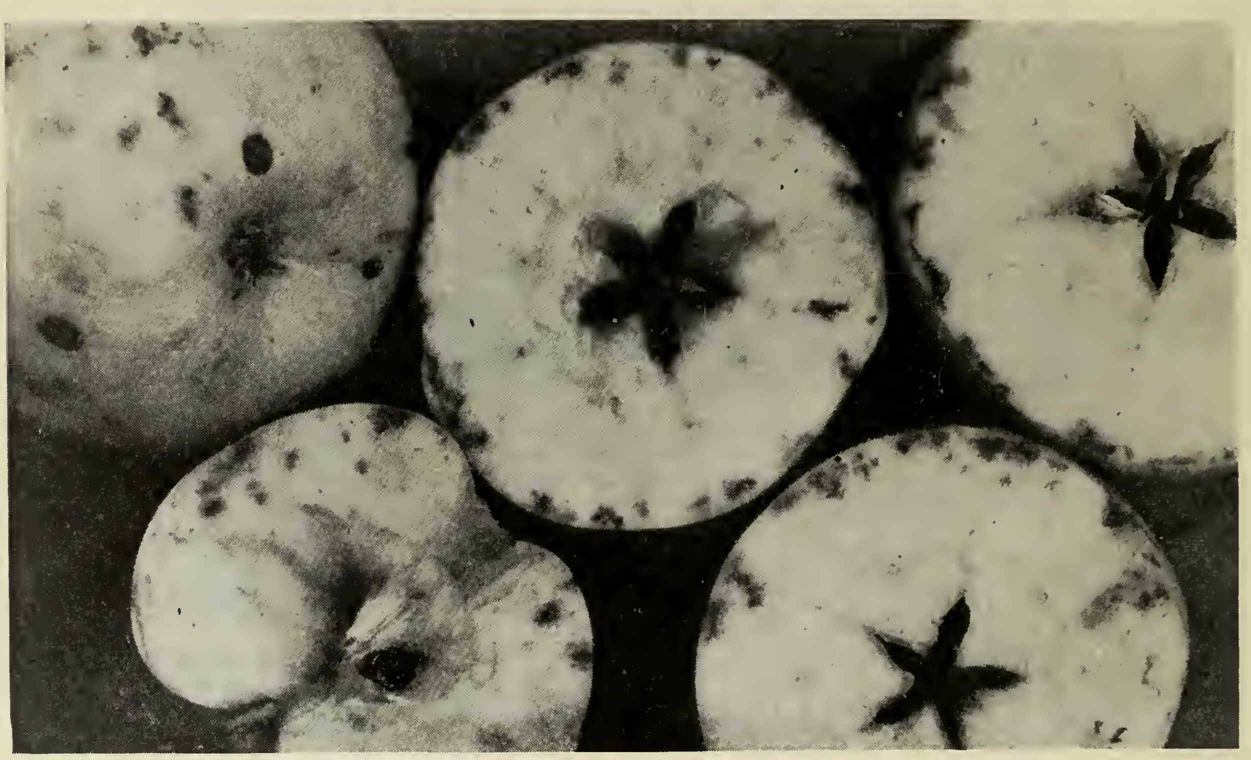


FIG. 13.—Bitter pit in Newtown. The cause of this physiological disturbance is not fully understood, but it is known to be more serious in certain seasons than others and invariably is most severe on fruit from light-crop trees. Fruit from light- and heavy-crop trees should be segregated in the orchard to prevent mixing.

Losses from bitter pit in British Columbia have been especially serious in Cox Orange, Northern Spy and Newtown, but the disorder has also been observed in many other varieties. It has been most prevalent in fruit produced by young trees, trees carrying a light crop, and trees which have been unduly stimulated by heavy applications of nitrogen or by heavy pruning.

Reduction of losses from bitter pit can be brought about by several means. Cultural operations and fertilizer treatment should be designed to produce medium-sized rather than very large fruit which is especially subject to bitter pit. It is most important to avoid heavy applications of nitrogen.

Harvesting at the correct stage of maturity is an effective means of reducing bitter pit. In this connection, the starch-iodine test has proved very useful in determining the desirable stage of maturity at which to pick Newtown. Maturity reaction of this variety to the starch-iodine test is illustrated in Figure 2.

Fruit from young and light-crop trees should be picked separately and kept segregated from the rest of the crop. This will prevent it from being mixed with the main crop produced by heavy-bearing trees. Such mixing has often necessitated costly repacking. Regardless of whether or not fruit from light-crop trees and young trees is affected with bitter pit, it should not be kept for long storage. Where bitter pit is prevalent it may be advisable to dispose of such fruit to a processing plant or even leave it in the orchard.

With the Newtown and Northern Spy varieties it has been found that fruit which is stored promptly at 30° to 31°F. develops less bitter pit than that which is delayed at higher temperatures before storage or held at 40°F. With these varieties, fruit which is thought to be susceptible to bitter pit should be held loose at 30° to 31°F. for two months after which affected fruits can be removed during the process of grading and packing.

Jonathan Spot

Jonathan spot is manifested by dark-coloured superficial spots which vary in size from minute dots to a quarter of an inch or more in diameter. Usually the spots are roundish and centered on lenticels but sometimes they are confluent, forming irregular shaped patches. The blushed side of the fruit is more susceptible to Jonathan spot than the unblushed side. By bleaching the red skin colour from a sample of apples with sulphurous acid, the spots on an affected apple can be clearly defined as indicated in Figure 14.

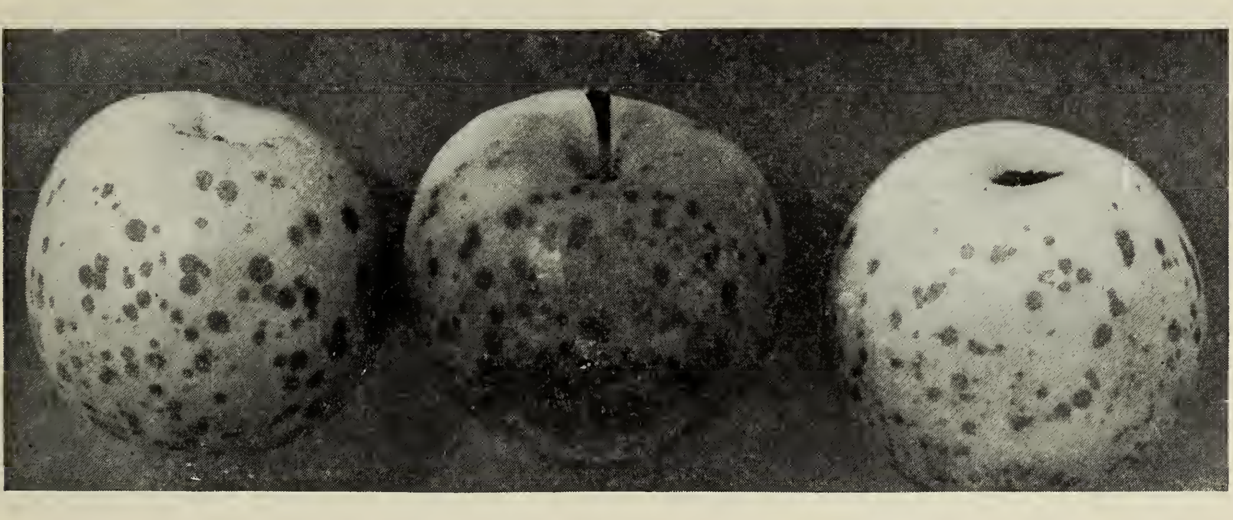


Fig. 14.—Jonathan spot on Jonathan. The red skin colour on these specimens was bleached out in order to make the spots more conspicuous. Caused by overmaturity and reduced in severity by low temperature storage.

The Jonathan variety is especially susceptible to Jonathan spot. However, somewhat similar spotting is often seen on Rome Beauty and may be found on other varieties. The disorder is most prevalent on fruit which has been picked in an overmature condition and held in storage for a long time. Low-temperature storage delays and reduces, but does not entirely prevent, development of Jonathan spot. Control lies in picking the fruit at the proper stage of maturity, reducing it promptly to low temperature, and avoiding long storage.

Shrivelling

Shrivelling is evidenced by wrinkling of the skin. It is the result of loss of moisture from the fruit. Susceptibility to shrivelling is increased by picking the fruit in an immature condition. Furthermore, varieties such as McIntosh and Golden Delicious with thin skins are more likely to shrivel than those with thick waxy skins such as Delicious and Wagener. However, all varieties eventually shrivel if kept for long periods in a dry atmosphere.

Practical control measures consist of harvesting at the correct stage of maturity, and storing in air having a relative humidity of 80 to 90.

Freezing Injury

The problem of freezing injury to apples is frequently encountered. The question has received extensive investigation and a great deal has been written about it. Freezing injury can take place in the orchard or in the cold storage plant. Irrespective of where the injury occurs, however, the handling of affected fruit is fundamentally the same.

As a background for discussion of freezing injury, attention is drawn to the following physical changes that occur when an apple is frozen. An apple is composed of approximately 84 per cent water and 16 per cent solids, mostly sugars. The solids present act as "anti-freeze" with the result that the freezing point of apples is lowered to approximately 28·5°F. If the fruit is kept absolutely still, temperature of ice crystal formation may be still further slightly depressed due to the phenomenon of supercooling.

As the temperature of fresh apples is reduced in cold storage, ·9 B.t.u. of heat is released per pound for each 1°F. drop in temperature. This rate of heat removal remains constant down to the freezing point of 28·5°F. When the freezing point is reached a further release of heat takes place which is necessary to produce a "change of state" from a liquid to a solid condition. This is known as the "latent heat of fusion" and for apples amounts to approximately 122 B.t.u. per pound. This heavy release of heat required to produce a change of state constitutes a real safety factor or buffer, since exposure of apples to freezing temperature for relatively short periods will not necessarily cause freezing of the tissue. Thus for example, in the late fall, apples may stand 10°F. of frost or more overnight on the tree, or fruit may be loaded from storage into railroad cars in zero weather without actually freezing.

Apples in storage become frozen either because of too low air delivery temperatures or on account of cold air being allowed to impinge directly upon fruit, such as occurs with down-throw delivery ducts. It is strongly recommended that except under unusual circumstances delivery air temperatures be maintained at 28°F.—not lower, and that down-throw delivery ducts be converted, where possible, to the side-throw type.

Slightly frozen apples may appear normal but have a heavy wooden feeling, while severely frozen apples show a peculiar type of skin shrivelling accompanied by a translucent or water-soaked condition of the flesh. Following thawing, freezing injury in apples may vary from no actual browning of tissue to complete flesh discoloration. Two Delicious apples showing severe freezing damage are illustrated in Figure 15. Apples which have been slightly frozen may recover and appear entirely normal, except that they may have a slight alcoholic taste and develop mealiness earlier than normal apples. This condition is probably representative of most apples in commercial storages that have suffered slight damage from frost. Tissue damage from freezing injury is often difficult to differentiate from Jonathan-type breakdown.

Severity of freezing injury depends on temperature and duration of exposure to cold. Thus, several days exposure to a temperature of 27°F. to 28°F. may cause little or no injury, whereas only a relatively few hours exposure to 15°F. may cause permanent damage. Frozen fruit may be thawed with a minimum of injury provided it is not moved or jarred. Temperature of air used to thaw frozen fruit should preferably not exceed 36° to 40°F., in order to prevent accelerated ripening of unfrozen fruit in the same storage room. Apples frozen in boxes in the orchard should never be moved, but rather

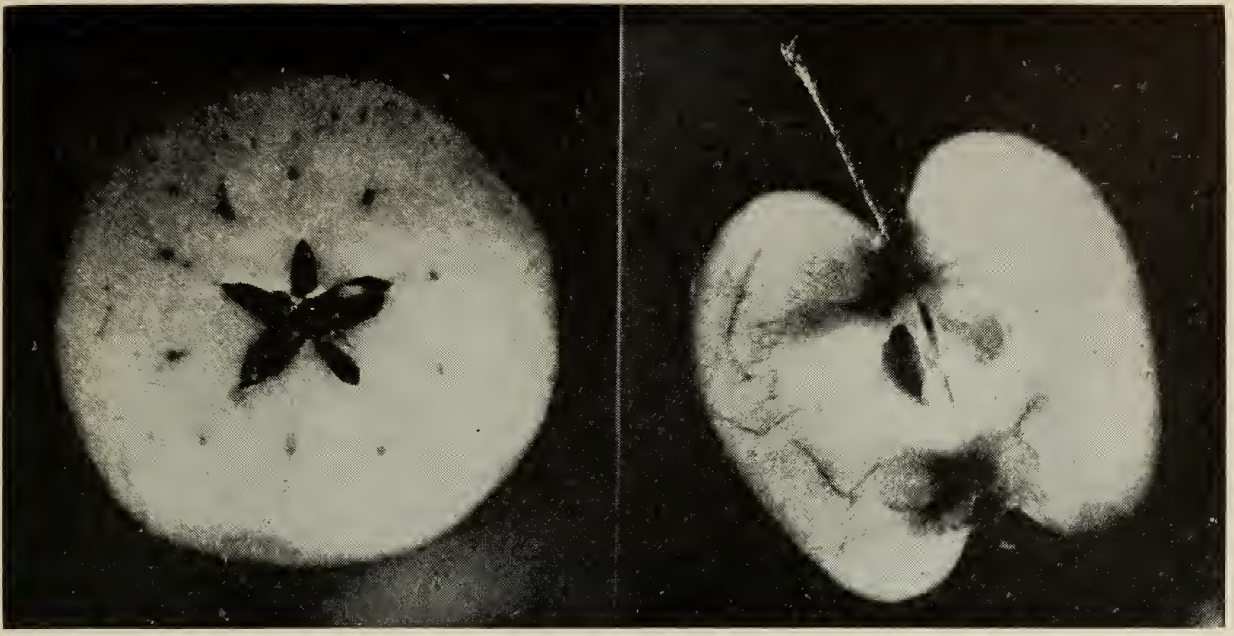


FIG. 15.—Severe freezing injury in Delicious. The suffused light brown coloured areas of the flesh are dry and mealy in texture.

heavily wrapped with canvas, paper or blankets until after the cold spell is over. When the frost has come out of them they may be moved under cover. If, however, weather forecasts indicate that continuous temperatures lower than 26°F. are to be expected for several days, the safest procedure is to move loose fruit from the orchard to cover as quickly as possible, before it has a chance to freeze.

FUNGAL ROTS*

Blue Mould Rot

The most common and serious storage decay is that produced by the fungus *Penicillium,* and known as blue mould rot. Typical blue mould rot is soft and watery, light to dark brown, with a musty taste and odour. This disease spreads rapidly through the fruit. As it develops, the affected area shrinks and cracks, and there appears on the surface a snow white mould growth which turns bluish-green as masses of spores are produced. Blue mould is illustrated in Figure 16.

The blue mould fungus usually attacks the fruit after it has been picked. Typically it is a wound parasite, using avenues of entry provided by mechanical injuries, or other rots and breakdowns. Less frequently it enters through the lenticels of healthy fruits.

Measures for reduction of blue mould rot to a minimum include careful handling of the fruit to avoid wounds or bruises, and its prompt transfer to cold storage. Rotten fruits should never be allowed to accumulate in or near a packing house, since they release large numbers of spores capable of infecting the shipments passing through.

Grey Mould Rot

Grey mould rot resembles blue mould rot in appearance, but is somewhat more firm, and lacks the musty taste and odour. At cold storage temperatures, mould growth seldom appears on the skin surface, but fruits removed to room temperature develop rapidly into masses of grey mould. Grey mould is illustrated in Figure 17.

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* Contributed by M. F. Welsh, Laboratory of Plant Pathology, Summerland, B.C.

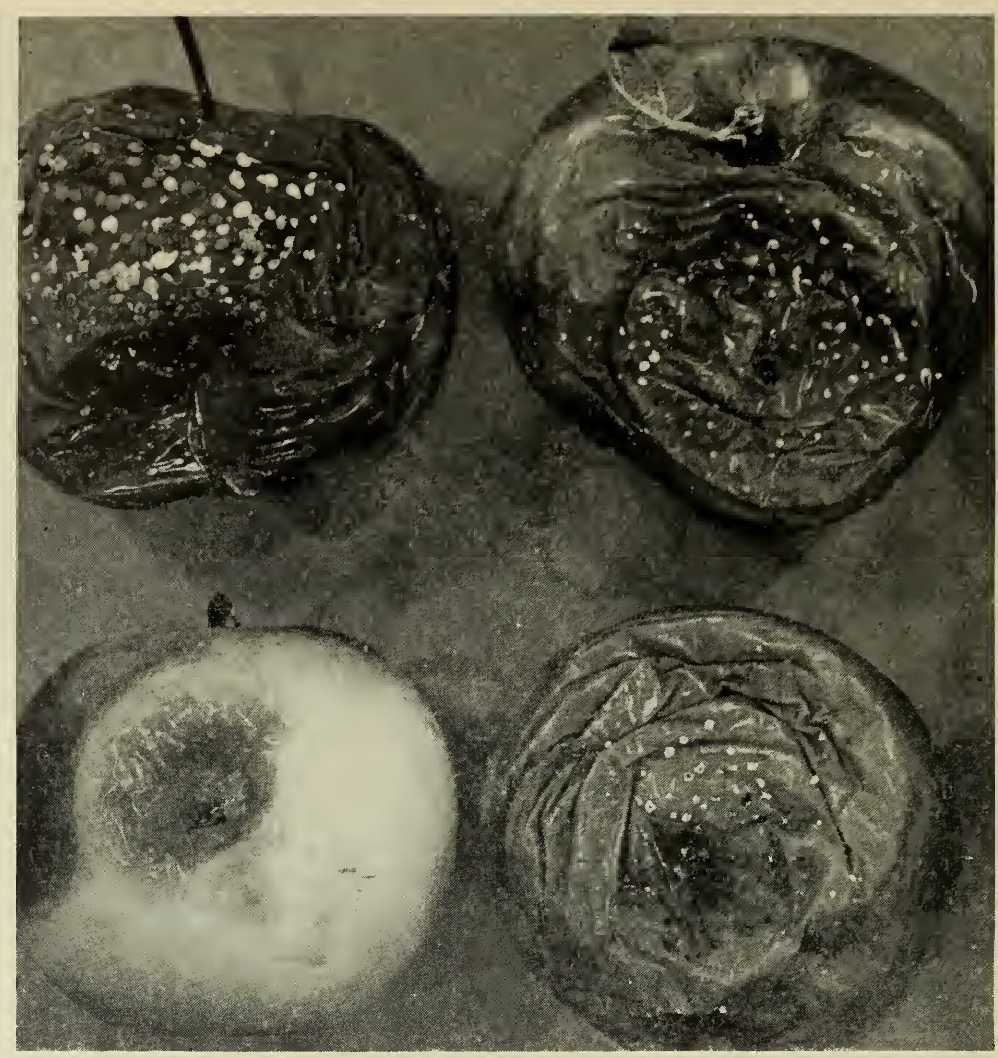

FIG. 16.—Blue mould rot on McIntosh caused by the fungus Penicillium expansum. Rots are started in broken areas of skin caused by stem punctures, bruising or box cuts.

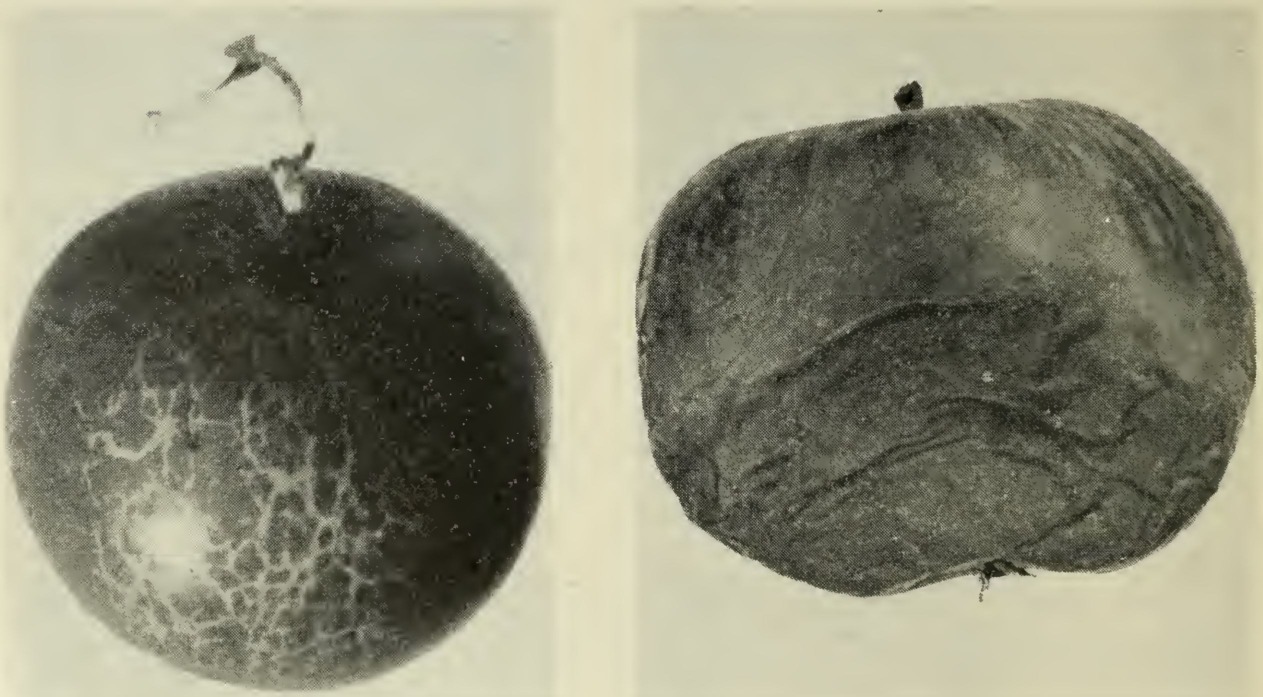

FIG. 17.—Grey mould rot (right) attacks apple through wounds, but works slowly at low temperatures. Apple powdery mildew (left) attacks apple during early part of growing season causing net-like russeting. When placed in storage apple shrivels markedly owing to loss of moisture from injured area. *Photos by S. R. Cannings and T. B. Lott.*

Although grey mould is even more active than blue mould at room temperatures, its development is very slow under cold storage conditions. At all temperatures it will attack apple fruits only through wounds. Preventive measures are exactly as for blue mould rot.

Bull's Eye Rot

Bull's eye rot is a slow-spreading, firm-type of decay. It appears first as a brown depressed circular spot, often with a yellow centre, the entire spot gradually becoming brown and leathery. Usually, as the spot grows, fungus fruiting bodies develop in concentric rings on the surface. Bull's eye rot in various stages is shown in Figure 18.

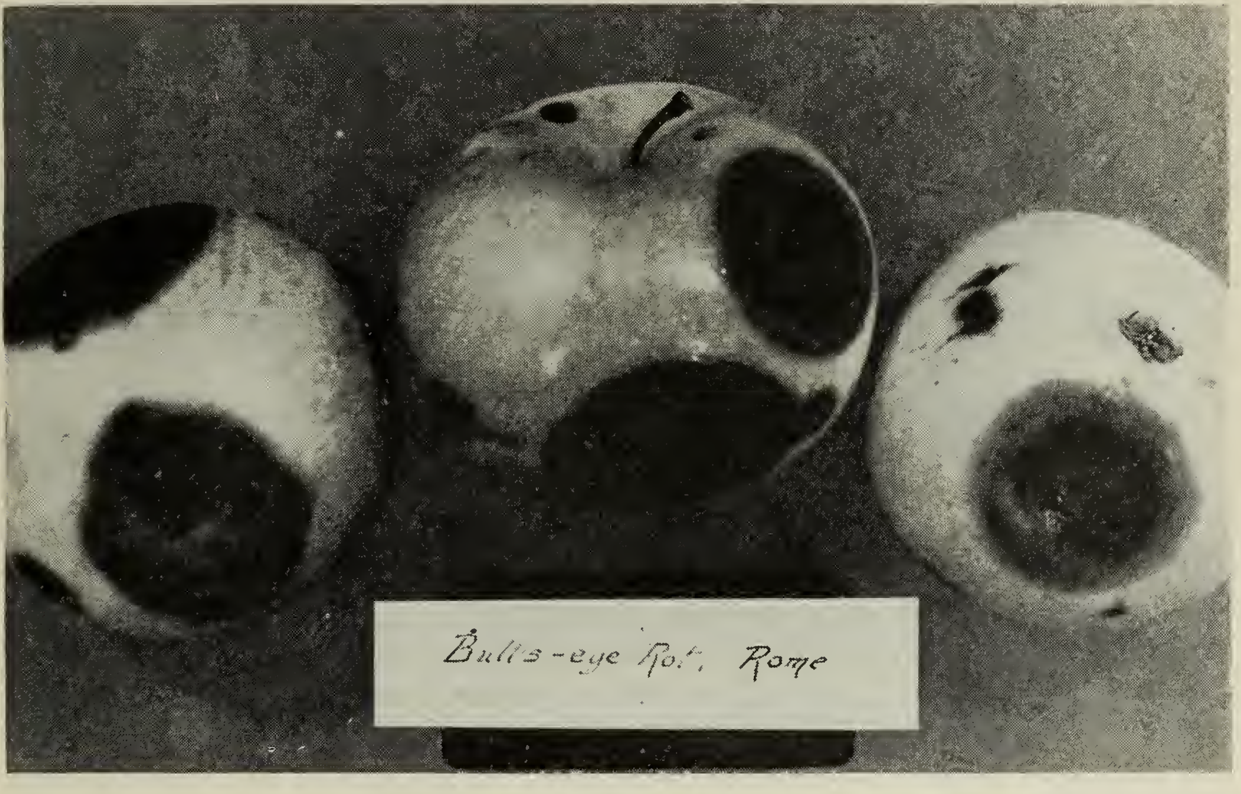

FIG. 18.—Bull's eye rot of apple caused by same organisms causing perennial canker and apple tree anthracnose in trees. Infections take place through skin lenticels before picking, and the rot develops slowly in storage.

Identical symptoms of bull's eye rot are produced by two fungi, one which causes perennial canker of apple trees, and one which causes apple tree anthracnose. In either case infection of the fruits takes place in the orchard, but the rot develops slowly and shows up only after the fruit has been in storage for some time. Slow development occurs at 32° F., more rapid development at higher temperatures.

Control of the perennial canker and anthracnose diseases in the orchard provides the most effective means of preventing outbreaks of bull's eye rot in the fruit. In orchards where either disease is severe, boxes of picked fruits should never be piled under trees, since even light rains will wash down fungus spores.

Storage Scab

In apple scab districts the development of fruit scab may continue in storage, either as further growth of the pin point lesions already evident, or the appearance of new lesions.

The symptoms vary greatly. On McIntosh fruits particularly, they may correspond closely with the more familiar orchard symptoms of apple scab. More commonly, however, the spots which develop in storage are small, sunken, and shiny black, resembling blots of ink, as shown in Figure 19.

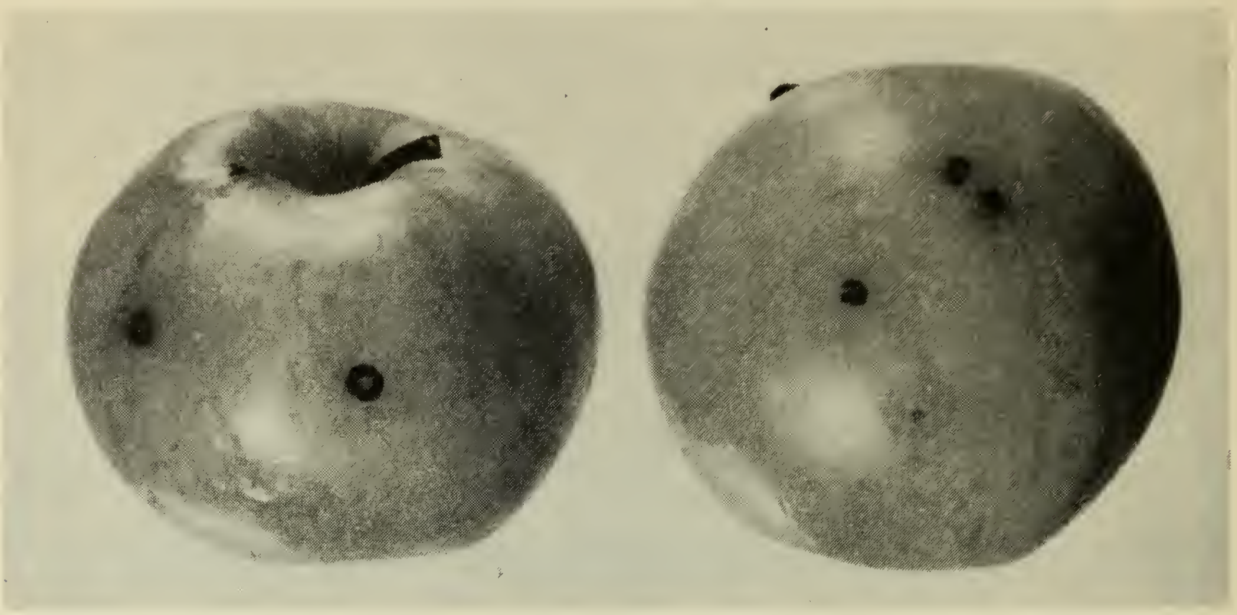

FIG. 19.—Storage scab. This disease is the same as apple scab found on fruit at picking. These lesions result from infections occurring prior to harvest, but may not make their appearance until as much as six months after fruit is placed in storage. *Photo by S. R. Cannings.*

Although all these lesions are the result of infections which occur before the fruit is picked, they may make their appearance as late as six months after the fruit is placed in storage. Sometimes apples which are apparently quite sound at picking time may develop severe storage scab late in the winter. The disease will develop slowly at storage temperatures as low as 32° F., but thrives best under conditions of high temperature and high humidity.

The most effective preventive measures are those carried out prior to entry of the fruit into storage. The recommended apple scab spray schedule thoroughly applied should prevent the appearance of storage scab. Where its occurrence is common, however, an additional cover spray may be necessary in wet years.

Apple Powdery Mildew

Although powdery mildew attacks apple fruits only during the early part of the growing season, the effects of the disease are particularly marked during storage.

At picking time, mildew infection shows as a net-like russeting of the apple skin, as illustrated in Figure 17. During storage this russeting allows abnormally rapid water loss through the skin of the fruit, with consequent shrivelling. This water loss is most serious at high temperatures and low humidities.

Powdery mildew fruit infection can be prevented satisfactorily by use of the spring spray program recommended by local Department of Agriculture officials.

SUMMARY OF STORAGE DISORDERS AND ROTS

Disorder	Causes	Control
Water Core	Overmaturity Exposure to intense sunshine	Harvest at correct maturity Slight water core usually disappears during storage
Jonathan Breakdown	Light crop Overmaturity	Segregate fruit from light and heavy crop trees. Harvest at correct maturity.
Mealy Breakdown	Overmaturity High temperatures Prolonged storage	Harvest at correct maturity Store promptly at low temperatures. Market during proper season.
Soggy Breakdown and Soft Scald.	Immaturity Delayed storage Low temperature	Harvest at correct maturity. Unless susceptible varieties can be stored at 30-31°F. within 4 days of harvest, store at 36°F.
Core Flush	Overstimulation of trees Large size apples Immaturity Prolonged storage at 30-31°F.	Avoid heavy applications of nitrogen. Sell large sizes first. Harvest at correct maturity. Market in proper season.
Apple Scald	Immaturity Various gases given off by ripening fruit.	Harvest at correct maturity. Forced air circulation and ventilation. Packing apples in oiled wraps.
Bitter Pit	Overstimulation of trees Light crop Immaturity Delayed storage	Avoid heavy applications of nitrogen. Segregate light-crop fruit. Harvest at correct maturity. Store promptly at 31-32°F.
Jonathan Spot	Overmaturity Prolonged storage	Harvest at correct maturity. Market in proper season.
Shrivelling	Immaturity Low humidity	Harvest at correct maturity. Maintain relative humidity 80 to 90.
Freezing Injury	Low delivery air temperature in storage and poor air circulation patterns.	Maintain delivery air temperature at 28°F. and avoid cold air blowing directly on fruit.
Blue Mould Grey Mould	Fungal spores entering fruit through skin injuries.	Careful handling to avoid stem punctures and bruising.
Bull's Eye Rot	Fungal spores of the same kind as produce perennial canker and anthracnose.	Control of perennial canker and anthracnose in apple trees.
Storage Scab	Same fungus that causes scab in the orchard.	Good orchard spraying to control apple scab.
Powdery Mildew Russeting.	Powdery mildew fungus	Adherence to recommended spring spray program.

MISCELLANEOUS INFORMATION

Storage Plant Sanitation

Most operators of storage plants become concerned at some time or other with the control of mould in their warehouses. Mould spores are widely distributed throughout the atmosphere and on all objects in contact with the atmosphere. Fruit coming into the packing house from the orchard has been shown to carry a heavy spore load, but these spores seldom cause rotting unless they gain entrance to the flesh through stem punctures or severe bruising injury.

The spore load in packing houses is, of course, somewhat higher than in other buildings due to the unavoidable presence of some decaying fruit at various times.

For this reason, plant sanitation measures should be designed to remove promptly all decaying fruit; and particularly at the end of the apple storage season to dispose of all odds and ends of partly filled boxes of apples which frequently are left lying around a warehouse. Such fruit produces quantities of mould spores.

Due to high humidities (80 to 90 per cent) in cold storage plants, patches of blue mould on floors, walls and ceilings often show up toward the spring of each year. While the attacks of such mould are rather superficial they are nevertheless unsightly, and do contribute to the spore load in the building.

There are various methods of cleaning up mould infections, such as burning sulphur in the room, applying whitewash, or formaldehyde fumigation; but one of the best treatments is to scrub infected surfaces with a detergent followed by a hypochlorite spray. A good detergent is a one per cent solution of tri-sodium phosphate scrubbed vigorously into the wood. This is followed by a spray of sodium or calcium hypochlorite at a strength to give 0·8 per cent available chlorine. This treatment, as well as other treatments, should be given in the spring after the storages are emptied, and doors left open for removing the chlorine fumes. Mould-infected surfaces may also be sanitized by a detergent scrub followed by one of the commercial chlorophenol compounds.

Rodent Eradication

In some seasons, field mice entering storages by way of loose boxes of fruit from the orchard may cause very serious damage to both loose and packed apples. There are two practical means of killing mice in storages without damage to apples, both approximately equal in cost. With one method, mice are killed by carbon monoxide fumes from tractors whose exhaust gases are piped into the storage. It has been found that the carbon monoxide produced by one tractor or truck in 3 to 5 hours is sufficient to kill all the mice in a storage with a cubical content of 100,000 cubic feet. All doors and outside ports in the storage are tightly closed, and the exhaust fumes pumped into the fan room where the circulating action of the fan soon carries the fumes to all sections of the storage. Mice in cages are placed for observation purposes near an outside port, where they can be inspected from time to time to determine the length of time required to produce killing. To make sure of a thorough job, it is advisable to run the tractors for a further thirty minutes after the mice in the cages are dead.

After the fumigation period, the door of the fan room should be opened to outside air and all doors in the plant opened. The rapid change of air produced by the cold storage fan unit makes it quite safe to enter the storage 30 minutes after the doors are opened. *As carbon monoxide is very poisonous, it is highly important that no one enters the storage during fumigation and all employees should be amply warned to this effect at the start of the treatment.* Any one who has collapsed from carbon monoxide poisoning should be kept warm and given artificial respiration.

The other method of fumigation for mouse control involves the use of methyl bromide at the rate of one-quarter pound per 1,000 cubic feet of free air space. Methyl bromide is the standard rodent and insect fumigant for ships and most types of warehouses storing non-perishable food products. This material is supplied as a liquid under pressure in cylinders. At temperatures above 40°F. it forms a gas and below 40°F. it exists as a liquid. When it is released into a 30°F. storage as a liquid, it vaporizes relatively slowly unless evaporation is assisted by a strong fan located in the area where the material is being liberated.

Since methyl bromide is a heavy gas (3·27 times the weight of air), it is necessary to provide air circulation to all parts of the storage room to prevent stratification. This can be achieved by the use of powerful fans in the room or by using the central coil room fan. As with the carbon monoxide treatment, mice should be placed in test cages near external ports to determine necessary killing period.

Where the gas concentration is maintained, a four-hour exposure is sufficient to kill the mice. However, methyl bromide gas will leak excessively from doors and ports unless great care is taken to seal the cracks. Leaks may be detected with a halide leak detector which may be borrowed or rented from any domestic or commercial refrigeration service dealer. When the detector used at an opened door or port shows a flame colour of strong blue green, it is advisable to introduce an additional 25 per cent of the initial quantity of methyl bromide to the storage.

Following fumigation with methyl bromide, the storage should be opened and thoroughly ventilated before entry by workmen. If it is necessary to enter a storage during fumigation with methyl bromide, an organic canister respirator must be worn.

Either the carbon monoxide or methyl bromide treatment applied according to the foregoing instructions will give a complete kill of rodents, with no apparent harmful effects upon the fruit.

Testing of Thermometers

Accurate reading thermometers are an important part of the fruit storage operator's equipment. Since apples are stored at temperatures so close to their freezing point, correct thermometer readings must be available at all times to prevent possibility of frost damage. Moreover, it has been shown that differences of only 2°F. around 32°F. may add or subtract as much as 25 per cent to or from the keeping life of apples. In addition, slight differences in holding temperatures with some varieties are sufficient to cause development of low temperature disorders. Thermometer inaccuracies of even one or two degrees Fahrenheit represent, therefore, a hazard to successful fruit storage.

Three kinds of thermometers are in common use in apple storages; that is, the weekly recording clock-type, the ordinary wall type, and pocket size pointed-tip meat thermometer for taking fruit core temperatures. Since it is not economical to purchase certified correct laboratory thermometers for fruit storages, a simple method for testing accuracy of existing thermometers is necessary. This can readily be done by immersing the thermometer in a mixture of melting ice and water. Plenty of cracked ice should be placed in the water and the mixture well stirred. The temperature of the ice water thus obtained is exactly 32°F. If the thermometer reads 32°F., it can be considered accurate in this range; if it reads higher or lower than 32°F., allowance must be made for the error when taking readings.

New thermometers showing more than one degree of error should be returned promptly to the supplier for replacement. Recording clock thermometers, if found to be in error, should be sent to the factory for adjustment and cleaning.

Pressure Testers and Their Uses

The development of the Magness portable pressure tester in 1925 and its subsequent manufacture by the D. Ballauf Company marked a distinct forward step in fruit maturity testing. It has proved of particular value in determining harvesting maturity for pears, but is, at best, only a rough guide for gauging picking time for apples. On the other hand, the pressure test is used in some areas as a guide for determining ripeness of apples in storage. In the Interior fruit districts of B.C., the ranges of pressure shown in Table 5 have been found to be useful in determining condition of cold storage apples.

TABLE 5.—RIPENESS OF APPLES IN STORAGE AS DETERMINED BY THE BALLAUF PRESSURE TESTER USING 7/16 INCH POINT

Variety	Firmness	
	Firm	Firm Ripe
	lb.	lb.
McIntosh	16·5 to 13·0	13·0 to 10·0
Jonathan	16·5 to 13·5	14·0 to 10·5
Delicious	17·5 to 14·0	15·0 to 11·0
Rome	19·0 to 14·0	14·0 to 11·0
Winesap	19·0 to 14·0	15·0 to 12·0
Stayman	16·5 to 14·0	14·0 to 11·0
Newtown	19·0 to 15·0	16·0 to 12·0

The pressure tester comes with points of two sizes, $\frac{5}{16}$ inch for pears and $\frac{7}{16}$ inch for apples. In preparing fruit for the test, a thin paring of skin about $\frac{1}{2}$ inch in diameter is removed. It is desirable to take two readings per apple, one on the green and one on the blush side of the fruit. This is because the blush side is often one to two pounds firmer than the unblushed side. Moreover, since large apples usually test softer than small apples of the same colour grade, allowance must be made for this factor. A sample of apples for pressure testing should consist of at least ten and, preferably, twenty fruits. Contrary to general belief, temperature of fruit at time the test is taken has little influence on the firmness recorded.

In making a pressure test, special precautions should be taken to eliminate errors which may be caused by faulty methods of manipulating the tester. Two rules should be observed: (1) point the pressure tester at right angles into the fruit, and (2) insert the tip into the fruit with a firm, steady pressure until the depth mark is reached.

SUMMARY OF HARVESTING AND STORAGE RECOMMENDATIONS

Variety	Maturity Indices	Storage Temperature
Wealthy	Seeds part brown, flesh white	30–31°F. within 2 days of harvest or 36°F.
McIntosh	Seeds brown all over, flesh white, 135 to 140 days from full bloom.	30–31°F. within 2 days of harvest.
Jonathan	Skin colour as shown on colour chart, Figure 1.	30–31°F. within 2 days of harvest or 36°F.
Delicious	Flesh white, 155 days from full bloom	30–31°F. within 2 days of harvest.
Golden Delicious	Skin colour pale yellow, two pickings desirable.	30–31°F. within 2 days of harvest or 36°F.
Spartan	Two weeks after McIntosh	30–31°F. within 2 days of harvest.
Jubilee	Three weeks after McIntosh	30–31°F. within 2 days of harvest.
Newtown	Starch-iodine reaction as shown in Figure 2; about 155 to 160 days from full bloom.	30–31°F. within 2 days of harvest.
Northern Spy Spitzenberg Wagener Rome Stayman Winesap	These varieties usually mature after Newtown. the harvesting dates for each variety being determined by such factors as development o red colour, adherence of fruit to spurs, and danger of loss from frost.	30–31°F. within 2 days of harvest.

ACKNOWLEDGMENTS

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Except where otherwise indicated, the photographs used in this bulletin are the work of J. E. Britton, now retired from the staff of the Dominion Experimental Station, Summerland, B.C.

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